Hydrologic Assessment

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1 Executive Summary

The Interim Operational Plan (IOP) is the most recent incarnation in the long and complex, evolution of water control in Everglades National Park (ENP). The IOP utilized structural features of the C-111 project to refine the Interim Structural and Operational Plan (ISOP) to improve hydrologic conditions in areas of critical habitat while providing water supply and flood protection for the region. While many of the objectives of the IOP were met, there were also some related side effects. The following is a summary of the major findings.

1.1 Water Conservation Area 3A

According to the EIS (USACOE, 2002), Water Conservation Area-3A (WCA-3A) was predicted to increase in depth; this conclusion was a major factor in the "Finding of Significant Impact" in that EIS. The increase was expected because of the periodic closure of the S-12 structures, which release water from WCA-3A into Everglades National Park (ENP).

The analysis presented in this report indicates that WCA-3A was likely lower under ISOP/IOP than it would have been under Experimental Water Deliveries (EWD) operations. The addition of Zone E1 appears to have compensated, even overcompensated, for the partial closures of the S-12 structures. Moreover, aggressive releases of floodwater from WCA-3A during the wet season into the South Dade Conveyance System (SDCS) also had the effect of keeping water levels lower than anticipated.

1.2 Water Conservation Area 3B

There is no issue related to the Cape Sable Seaside Sparrow (CSSS) directly tied to WCA-3B. For this reason, the impacts from ISOP/IOP were expected to be small, although the EIS did anticipate the possibility of higher water levels related to increased seepage from WCA-3A.

Review of the available hydrologic record revealed that WCA-3B is significantly lower. This is not a result of any operation related to the CSSS. Rather, it appears to be tied to a change in the operational philosophy at S-335, which controls the canal along the eastern boundary of WCA-3B. This is a wholly undesirable, adverse, and unintended consequence of ISOP/IOP implementation.

1.3 Central and Western Shark Slough

The primary objective in implementing the ISOP and IOP was to reduce damaging high water levels in the CSSS habitat along the western flank of Shark Slough. The purpose was not only to provide an improved opportunity for nesting, which is directly related to water levels during the breeding season, but also to allow the habitat to recover from prolonged unnatural flooding.

According to this analysis, the ISOP/IOP operations achieved the fundamental goal of reducing water levels in western Shark Slough and CSSS habitat. However, because this was accomplished by reducing the total volume of water crossing Tamiami Trail, the result was also significant reductions in water levels and hydroperiods in central and lower Shark Slough.

1.4 Northeast Shark Slough

In a restored, functional Everglades, Northeast Shark Slough (NESS) would receive the major portion of flow, would experience peak water depths exceeding 2 feet, and would dry out only in the severe droughts. Although the Reasonable and Prudent Alternative (RPA) called for diverting water from western Shark Slough into NESS, this was deemed impracticable for ISOP and IOP, primarily because of the potential effects on the 8.5 Square Mile Area (8.5 SMA). The expectation in ISOP was that NESS would experience no significant changes, and that, with the removal of the lower end of L-67ext, there was a possibility of some improvements in water levels and hydroperiods in IOP.

Upon examination of the available hydrologic data, it was found that ISOP/IOP likely resulted in an unexpected overall decrease in water levels and hydroperiods in NESS. Moreover, the net decreases were highest near L-31N, and tended to lessen as one moved westward. An additional, though probably secondary, possible cause of these lower water levels is the overall reduction in flows across Tamiami Trail. The general decrease along this boundary partially accounts for these effects in NESS. The removal of the lower portion L-67ext levee was considered to be an unlikely possible cause, as reductions were observed before the levee was removed. However, the existing hydrologic network was inadequate to determine the effects of the levee removal. The overall conclusion was that ISOP/IOP operations had an unintended adverse impact in NESS, primarily related to operations in L-31N.

1.5 The Rocky Glades

IOP different most significantly from ISOP in the construction of additional buffer reservoirs, or detention areas, between L-31N and ENP. The expectation was that these reservoirs would compensate for the reduction in L-31N water levels, which had resulted in over drainage and a general decline in habitat quality in the Rocky Glades. These reservoirs would serve as a hydraulic barrier, decreasing seepage losses from ENP, and improving water levels, hydroperiods, and the natural response of the wetlands to rainfall.

The analysis of the effects of ISOP/IOP in the Rocky Glades proved very difficult. The network of gauging stations is not adequate to get a complete picture of the response. Moreover, the data smoothing that was required to look for general trends did not allow for a quantitative investigation of the effects of pre-storm operations. However, the network that was in place was able to detect the most likely expected benefits.

Analysis of the available information showed that ISOP/IOP operations resulted in an apparent slight increase in water depths and small reduction in seepage losses. It does not appear that the significantly decreased water levels in the lower L-31N canal translated into significant reductions in marsh water levels, as had been the result when canal stages were lowered during the EWD Program. That is, the ISOP/IOP structures were probably sufficient to offset reductions in L-31N canal stages, but not sufficient to result in significantly improved water depths and hydroperiods, as anticipated in IOP.

1.6 Upper Taylor Slough

The region just west of the Frog Pond, where the C&SF Project has historically delivered water to Taylor Slough, is referred to in this report as upper Taylor Slough. Water deliveries to Taylor Slough underwent significant changes from Test 7 Phase I to ISOP, and again from ISOP to IOP. In IOP, the USACOE constructed significant engineering works in the Frog Pond to improve the water deliveries from the new pump station, S-332D. The expectation for IOP was that volume, timing, and distribution of inflows to Taylor Slough would become more natural.

A prior analysis of the ISOP operations indicated that the ISOP resulted in wholly unnatural and very undesirable impacts in upper Taylor Slough. However, IOP appears to have largely corrected those problems. The new operational scheme and structures represent a significant improvement. More natural wet season recession patterns, a greater spatial extent of surface water during the wet season, and a possible decrease in seepage losses have been observed since the implementation of IOP. All these suggest that IOP resulted in more natural timing and distribution of inflows to Taylor Slough.

1.7 Lower Taylor Slough and the Eastern Panhandle

The construction of S-332D made it possible to divert flood discharges drained from the Rocky Glades back into Taylor Slough rather than passing those flows down C-111 and into the Eastern Panhandle of ENP. In both the ISOP and IOP, operations were designed to do exactly this. The expectation was that by putting the flows into Taylor Slough, they would flow down Taylor Slough and enter Florida Bay much further west than if they were routed down C-111. This would also reduce the frequency of direct freshwater discharges into Barnes Sound.

Through review of the hydrologic information, it is clear that direct surface water discharges from L-31N into C-111 have been significantly reduced. However, this reduction in surface water discharges has been almost exactly offset by an increase in groundwater seepage into C-111. No significant improvement was observed in flow characteristics into lower C-111 and the Eastern Panhandle. Nor was there any strong evidence of improvements in flow into lower Taylor Slough. Apparently, the significant benefits observed in upper Taylor Slough do not propagate very far downstream. The most likely obstacles to full dispersion of these benefits are canals (the lower L-31W and Aerojet canal) that capture groundwater and surface water and rapidly convey it back towards C-111. Moreover, low wet season operational levels in C-111 result in strong gradients and large seepage rates from Taylor Slough back toward C-111.

An analysis of the hydrologic effects of ISOP/IOP operations was conducted, focusing on ENP, WCA-3A and WCA-3B. The analysis was primarily based on an analysis of the observed hydrologic data collected from the existing monitoring network. Therefore, the observations and conclusions tend to be general, qualitative, and reliant on professional expertise.

2 Hydrologic Conditions and Operational Description

In determining the hydrologic effects of ISOP and IOP, there are two prerequisite analyses. The first is a review of hydrologic conditions, particularly rainfall. The second is a clear description of the operations; by characterizing the various operational regimes, one can focus investigation on observed versus expected responses. As the responses are a strong function of the interaction of operational policies and rainfall conditions, a clear picture of the rainfall and water level conditions is essential. This section begins with an examination of the hydrologic conditions, followed by a description of operations.

2.1 Hydrologic Conditions

2.1.1 Rainfall

In order to consider regional rainfall, a set of available historical rainfall data in and around the ENP area was compiled. Minor data gaps within the period of record for each site were filled in before computing average basin rainfalls. The data came from three different sources. Most daily rainfall data within the ENP boundary were retrieved from the ENP database called “DataForEver”. If missing data at a given site were minor (i.e., less than about 5% by year), daily gaps were filled in with concurrent records from nearby sites, otherwise the site was dismissed. This process identified 17 reliable rainfall gauge stations out of over 50 stations in and around the ENP area. An additional eight sites, which are mostly located outside the ENP boundary but have relatively long-term records, were also used. Monthly rainfall series from these eight sites were obtained from Ali and Abtew (1999), who made an extensive and reliable quality control of historical rain date from over 100 stations in the South Florida region. Their data extend from early 1900s to 1995. Thus, this study updates the data from 1996 to 2002 using the historical records retrieved from the DBHYDRO database that has been maintained by the SFWMD. Monthly average ENP rainfall series from 1914 to 2002 were computed from these two sources. In addition, the NOAA’s monthly rainfall data were used to fill in gaps, especially from October 1914 to March 1915 and from 1925 to 1926. The NOAA’s data are also used to extrapolate the record back to 1895. Table 1 summarizes the sites used from these three sources and Figure 1 displays site locations.

The study period includes the years 1995 to 2002, where 1996 to 1999 define the pre-ISOP/IOP years while 2000 to 2002 define the ISOP/IOP years. The rainfall conditions are shown in Table 2, which tabulates the annual, wet, and dry season totals for Everglades National Park and WCA-3. The annual average rainfall during the study period is about 3% higher than the long-term average, mainly due to higher wet season totals. The ISOP/IOP period is close to the long-term annual ENP average, but rainfall differs by approximately 8 inches annually and by about 6 inches during the dry period. During the study's time period the rainfall totals between ENP and WCA-3 differed, principally in that the wet season totals in WCA-3 were lower than the ENP totals. The most significant variation occurred during 2001 when the difference was 11 inches.

Figure 2 is a cumulative probability distribution function of the ENP basin rainfalls. Assuming a log-normal distribution, 1999 would approximate a 1-in-10 year wet season, 2000 was about a 1-in-4 year drought, 2001 was about a 1-in-3 year wet season, and 2002 was about average. Thus, one can state that overall rainfall during the period of the ISOP/IOP was about average.

Table 1. Selected rainfall stations used to compute average ENP rainfall series.

Source	Rainfall Station Name (# of sites)
DataForEVER	3A_S, FLA, FMB, HOMEFS, EVC, MIAMIFS, NP-206, RPL, S-18, NP-201, NP-203, OASIS, P-34, P-35, P-36, P-37, P-38, R-3110, RCR (17)
DBHYDRO (Ali and Abtew, 1999)	TAVERN, HOMESES1, HOMESES2, MIAMIAP1, MIAMIAP2, S-9, TAMIAMITR40, EVER-2 (8)
NOAA data	Florida Zones 5 (coastal Dade County) and 6 (ENP and part of WCA-3) (2)

Table 2. Basin rainfalls prior to and during ISOP/IOP

Basin	Period	Before ISOP/IOP					After			Historical Average
		1995	1996	1997	1998	1999	2000	2001	2002	
ENP	Year	78.2	52.3	56.5	61.6	70.0	49.4	61.1	54.7	38.4
	Dry	25.8	16.3	15.7	26.5	18.0	12.1	12.4	15.4	17.7
	Wet	52.4	36.0	40.9	35.2	52.0	37.4	48.8	39.3	56.1
WCA-3A	Year	79.5	48.7	50.2	56.3	65.2	46.2	50.2	44.9	
	Dry	32.9	17.2	15.8	22.5	18.7	13.8	12.4	13.6	
	Wet	46.6	31.5	34.4	31.9	46.5	32.4	37.9	31.3	

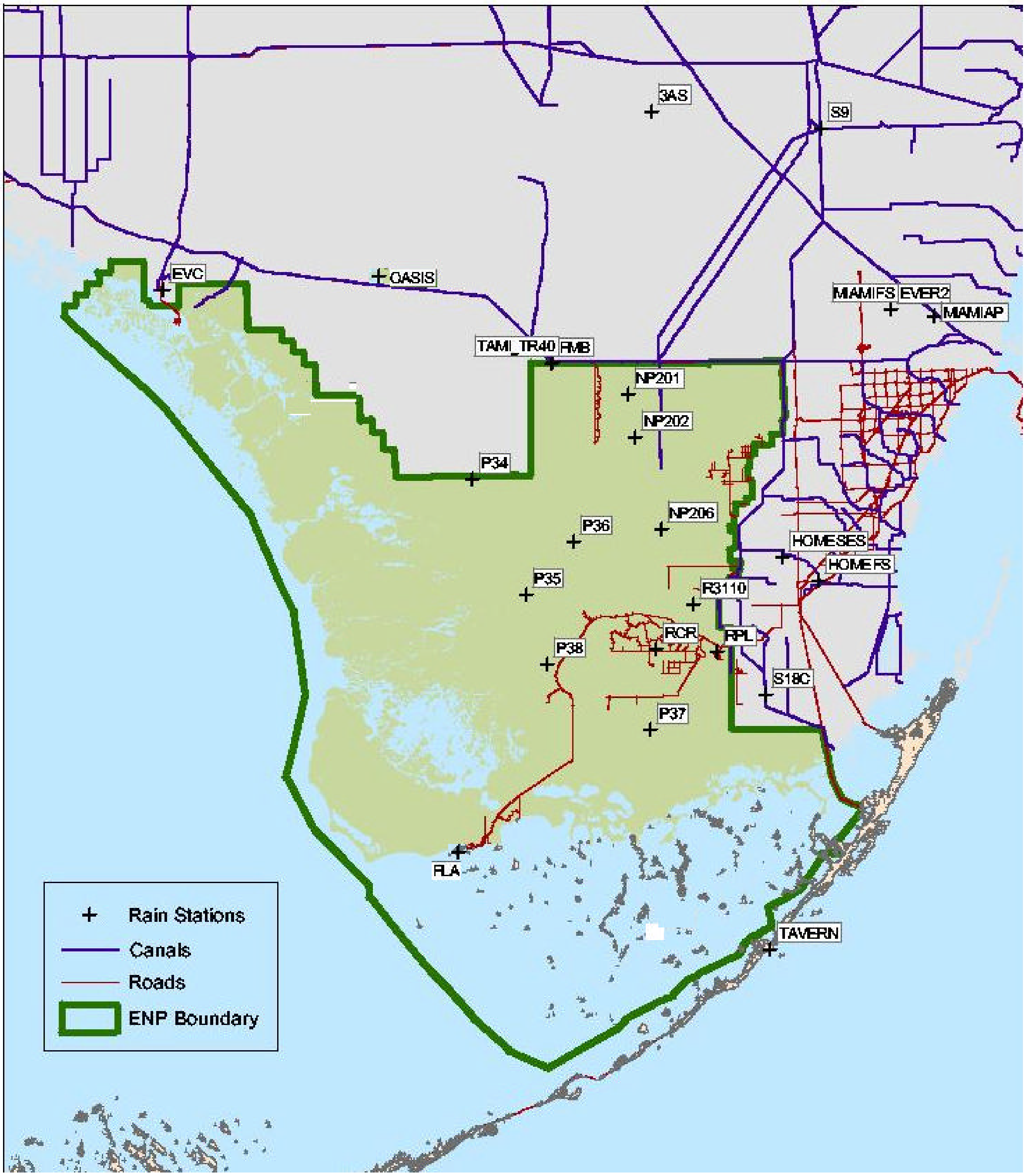


Figure 1. Rainfall station map

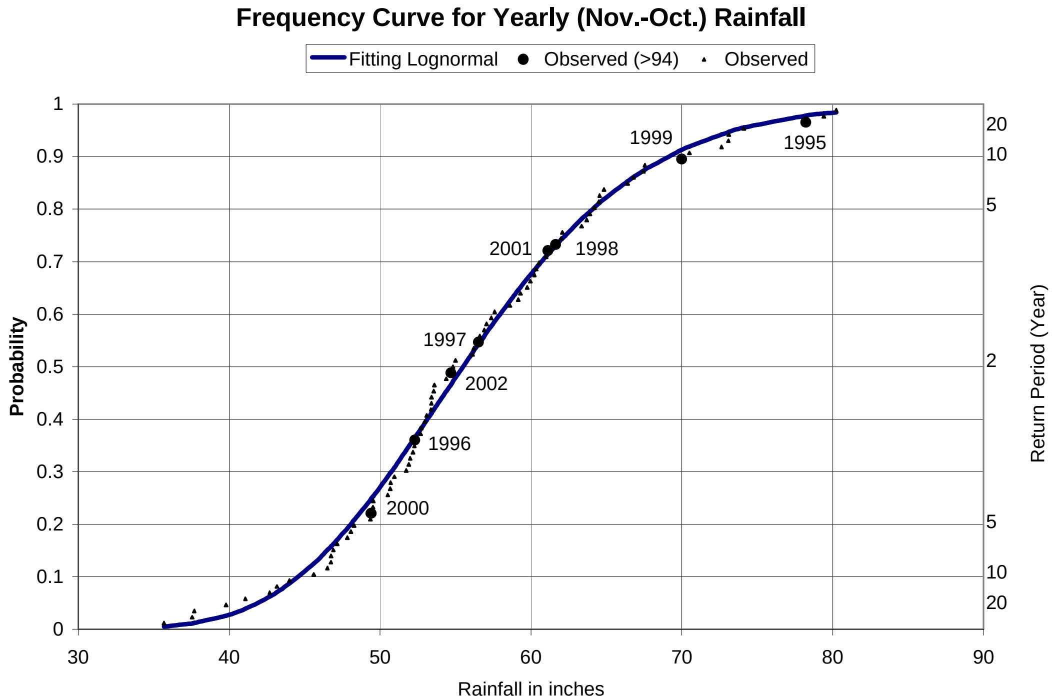


Figure 2. Cumulative distribution function for yearly rainfall.

2.1.2 Distinguishing Events

Although annual rainfall totals were "average", short-term rainfall events can have a dominant effect on operations and their hydrologic consequences. During the study period, there were several events that distinguished themselves from normal rainfall conditions. Two wet events occurred: Hurricane Irene and the "No-Name" storm. In addition, a drought occurred during the dry season of 2001-2002.

At gauges in ENP, Hurricane Irene dropped over 12 inches of rain in approximately 46 hours, beginning just before midnight on October 13, 1999 and ending just before midnight on October 15, 1999. In general, water levels increased by approximately one foot throughout the study area. The intense rain from Irene, coupled with the wet antecedent conditions, resulted in period-of-record maximum values at several stations, including some with over 50 years of record (Knight et al., 2001).

The "No-Name" storm occurred during the first week in October 2000 and dropped significant rainfall (6.8 inches) for a period of just over two days. This storm was a band of intense rainfall over the eastern edge of Shark Slough extending from Cape Sable in the southwest to the northeast corner of the ENP boundary. The band continued this same intensity and orientation across the cities of Hialeah and North Miami Beach to the coast (Knight et al., 2001).

This heavy storm was followed by a very dry beginning of the dry season. The first three weeks of November experienced no rainfall events greater than 0.1 inches. Monthly totals throughout the areas within and adjacent to ENP were only 30% of the normal monthly rainfall. In fact, 2000 was recorded as the second driest November at one ENP site and the third driest at another, both with periods of record extending back to 1949. Temporary relief from this dry period arrived in December with sporadic rainfall contributing to an above average monthly total for many of the sites within Everglades National Park. To the north of the Park in WCA-3A and WCA-3B conditions remained very dry with the area receiving about 50% of the average monthly rainfall.

Very dry conditions returned in January as most regions within and adjacent to Everglades National Park totaled between 30% and 50% of normal for the month. February was even drier, with below normal rainfall throughout the Park. These extremely dry conditions dissipated during March, as monthly rainfall totals were well above average throughout ENP. Rainfall during April was closer to the monthly normal in ENP, yet less than half of normal in WCA-3A and 3B. Higher than average rainfall totals were recorded throughout most of the Park during May. In summary, although the 2000-2001 dry season was distinguished by some very dry periods, the total rainfall was only slightly below average (Knight et al., 2001).

2.2 Description of Operations

2.2.1 Operations from 1996 to 2002

Since 1983, the operations of the South Dade Conveyance System (SDCS) have been governed by experimental, emergency and interim operations. The Experimental Water Deliveries (EWD) Program, in which a series of seven test operations were implemented, was in effect between June 1983 and December 1999. The Interim Structural and Operational Plan For Hydrologic Compliance with the CSSS Biological Opinion for the Year 2000 (ISOP) was in effect from December 1999 until January 2001. ISOP 2001 was formulated and implemented in January 2001 and remained in effect until June 2002. The ISOP 2001 supported the same objectives as ISOP 2000. In June 2002 the U.S. Army Corps of Engineers (USACOE) issued a Final Environmental Impact Statement (FEIS) for an Interim Operational Plan (IOP) "to create favorable hydroperiods in sparrow habitat in ENP while providing flood protection capability for developed lands east of the L-31N Canal." The IOP makes use of structural features from the Modified Water Deliveries (MWD) project and the C-111 project. IOP was intended to be an interim plan that will be replaced when MWD is completed.

These operational plans all work in tandem with the Water Supply and Environmental plan for Lake Okeechobee, the regulation schedules for the WCAs and the rainfall plans for Shark Slough and Taylor Slough.

The ISOP plan was implemented in response to a Biological Opinion issued by the U.S. Fish and Wildlife Service (USFWS). The Biological Opinion found that the operations under Test 7 Phase I of the EWD Program had placed the endangered CSSS in jeopardy. Along with the Biological Opinion, USFWS provided a reasonable and prudent alternative (RPA) recommending specific operational procedures to distribute water more evenly across the Northern boundary of ENP, to implement the EWD Plan Test7 Phase II, and to complete the MWD Project by 2003.

Because of concerns related to flooding in the 8.5 Square-Mile Area (8.5 SMA), a mixed urban and agricultural community located on the wet side of the L-31N protective levee at the edge of ENP, the RPA was not implemented and the ISOP was put into place. Under the ISOP, and later under the IOP, the S-12 structures on the northwest boundary of ENP were closed at the end of the wet season in order to reduce flooding of CSSS habitat during the nesting season. The most fundamental change in the SDCS operations occurred when Test 7 was terminated and the ISOP was initiated. Instead of routing water through the S-12 structures, excess water from the water conservation areas was delivered through S-333 and to the SDCS and the eastern boundary of ENP through S-334 and S-335, and canal stages along the Park's eastern boundary were lowered. This same operation persisted, with some modifications, in ISOP 2001 and IOP.

ISOP was revised in the March 2000 Environmental Assessment (EA) (USACOE, 2000) to include flood control operations and pre-storm operations. The ISOP operations in the March 2000 EA "seek to lower canal levels during the wet season and allow for higher water levels during the dry season. These operations also take into account real-time field conditions as measured in groundwater wells and forecasted storm events" to lower water levels in canals in order to expand flood protection capacity in Dade County. Table 3 compares the Test 7I (pre-ISOP) and Test 7II (RPA) maximum canal stages to the maximum canal stages indicated in the ISOP. Under ISOP the S-332B pump station and 160 acre 332B detention area were constructed. A weir, located on the western side of the 332B detention area was used to route excess water from the SDCS to ENP, raising concerns about water quality degradation resulting from discharge of urban and agricultural run-off into ENP.

In June 2002 the USACOE issued a FEIS presenting a final recommended plan, Alternative 7R, "to create favorable hydroperiods in sparrow habitat in Everglades National Park while providing flood protection capability for developed lands east of the L-31N Canal." Alternative 7R includes operation of structures previously authorized in the 1992 Modified Water Deliveries to ENP EIS and the 1994 and 2001 C-111 GRRs.

Table 3. ISOP, Test 7 Phase I, and Test 7 Phase II canal operational levels

Canal	Reach	Wet Season ISOP	Dry Season ISOP	Test 7I	Test 7II
L-29	S-333 to S-334	9.0	9.0	8.0	8.0
L-31N	S-335 to G-211	5.8	6.0	6.0	6.0
L-31N	G-211 to S-331	Angels criteria	Angels criteria	Angels criteria	Angels criteria
L-31N	S-331 to S-332B	4.7	4.7	5.0	5.2
L-31N	S-332B to S-176	4.7	4.7	5.0	5.2
C-111	S-176 to S-177	3.8	4.0	4.2	4.2
C-111	S-177 to S-18C	2.25	2.25	2.6	2.6

2.2.2 ISOP

During the fall of 1999 Tropical Storm Harvey and Hurricane Irene caused near record high water levels. To accelerate the water level recession rates, the USACOE developed an emergency Interim Structural and Operational Plan (ISOP), and implemented parts of it on December 15, 1999, curtailing the current operations, which were part of Test 7 Phase I.

Under Test 7 Phase I, flows to NESS via S-333 are stopped when G-3273 water levels are greater than 6.8 ft. Under the ISOP, flows from S-333 would not be stopped if G-3273 is above 6.8 feet (as they were previously). Instead, when G-3273 is above 6.8 feet, S-333 flows would be routed through S-334, G-211, and S-331. Under Test7I, S-333 was also closed if water levels in the Tamiami Canal (L-29) exceeded 8.0 ft.

ISOP operations also routed flow to the East Coast using the S-338 structure. ISOP specified, "When L-31N stage is above 5.5, make maximum possible discharges when permitted by downstream capacity," (USACOE, 2000). A new zone, Zone E1, was added to the WCA-3A regulation schedule, allowing additional releases out of WCA-3A (Table 4).

ISOP also specified that "A new temporary pump and buffer area will allow the increased operation of the S-333 structure to bring more water into the South Dade System. Specific components include modifying the trigger at G-3273 such that when G-3273 is below 6.8 flows would be passed into NESS. When G-3273 is at or above 6.8, flows from S-333 would be passed through S-334, G211, and S-331 and removed via either S-332B and/or S-332D. Discharges from S-332B would be directed into a buffer area about one half-mile west of L-31N within the footprint of the C-111 project. In addition, S-197 operations will be modified to allow limited discharges from C-111."

Table 4. WCA-3A regulation schedule

Zone	Description	S-12's	S-333/S-355A&B	S-151
A	Flood Release	open full unless S-12 A and B must be closed	maximum allowable discharge if G3273 < 6.8 ft NGVD or capacity is available via S-334/SDCS.	Maximum allowable discharge when WCA 3B stage is below 8.5 ft, NGVD.
	Upper Transition wet season	Discharge 45% of computed flow if S-333 is closed or discharging less than 28% of computed flow, S-12 must discharge at least 73% of computed flow	Discharge up to 55% of computed flow when permitted and for water supply to Everglades National Park-SDCS if G-3273 <= 6.8 ft.	Maximum allowable discharge when WCA 3B stage is below 8.5 ft, NGVD
C	Upper transition dry season	Close S-12's if discharge poses a threat to CSSS nesting	Same as Zone B	Maximum allowable discharge when WCA-3B is < 8.5 ft.NGVD.
D	lower transition dry season	Same as Zone C	Same as Zone B	water supply

Zone	Description	S-12’s	S-333/S-355A&B	S-151
E	Rainfall formula only	no regulatory releases	no regulatory releases	water supply
E1	Sparrow nesting	minimize use of S-12’s	maximum releases at S-142,S-151, S-31, S-337, S-335, S-333, s-355 A & B, S-334 when permitted by downstream conditions	maximum releases at S-142,S-151, S-31, S-337, S-335, S-333, s-355 A & B, S-334 when permitted by downstream conditions

The operation of S-335 is outlined in the March 2000 EA (USACOE, 2000).

> “S-151, S-31, S-337, S-335**: Use to move storage water from WCA-3A as downstream capacity is available.** These operations would not take place in Zone E of the WCA-3A regulation schedule unless using structures for water supply deliveries. S-335 will not be used when the downstream water levels are 6.0 ft NGVD or greater. Once the downstream water levels are 6.0 ft NGVD or less, then S-335 may be opened with the goal of achieving a 6.0 ft NGVD headwater upstream of S-335 before water is introduced via S-334.”

The operation of S-335 specified in the ISOP was aimed at moving storage water from WCA-3A. However, these operations also were used to lower regional water levels in WCA-3B and the Pennsuco wetlands (Mitchell-Bruker et al., 2001). In addition to these actions reported by the USACOE, operations at G-211 were tightened to more consistently maintain the headwater stage at 6.0 ft.

2.2.2.1 ISOP Implementation (January 2000-December 2000)

Emergency ISOP operations before the March 2000 EA included modifications to the pre-ISOP Test 7I operations to improve hydrologic conditions for the sparrow subpopulations. Operations after March 2000 included new operations to “lower canal levels during the wet season and allow for higher water levels during the dry season.” (USACOE, 2000). The following summary of the dry season operations was extracted from the ENP 1999-2000 Status and Trends report (Knight et al., 2001) and the USACOE After Action Report.

The most critical operation of the early 2000 wet season was to allow for early closure of the S-12 structures in order to maximize nesting opportunities in CSSS subpopulation A. The Corps diverted water from WCA-3A by closing the S-11 structures on November 12. In order to reduce flow to sub-population A, they closed S-12A on December 16th. The increased recession rate due to closing S-12A was apparent.

On January 5th, S-333 and S-334 were opened to divert additional water from WCA-3A. According to the USACE After Action Report: “During periods when G-3273 was above 6.8 feet and WCA 3A was above regulatory schedule, water was passed through S-344 and into L-31N (more than 42,000 acre-feet). No flood impacts on private properties have been reported along L-31N since the ISOP has been in place." In spite of this finding, the new wet season operations outlined by the USACE in the March 2000 EA, prescribed routing water from WCA-3A via S-151 and S-335, rather than through S-333.

On February 15th, about 10 days after WCA-3A had receded into Zone E1, S-12C and D were closed. On February 17 flows to the SDCS and S-332D were reduced. In the week following February 17th the pumping rate at S-332 was reduced from 536 cfs to 5 cfs. Water levels in upper Taylor Slough plummeted over 1.0 feet over the next ten days resulting in high and undesirable fish kills. On March 1st the new ISOP 2000 operating schedule was implemented for the SDCS. Discharges at S-332 and S-332D were reduced. S-332B began pumping on April 13 and wet season operations began on June 12.

A particular concern for ENP is the wet season operations that route water from S-335 to ENP when no water is being brought from the WCAs. This operation continued from June 2000 through December 2001. In addition, Zone E1 releases from WCA-3A depletes water storage early in the dry season, reducing the available water for late dry season environmental deliveries.

It was also apparent that under the ISOP, L-30 drained WCA-3B and the Pennsuco wetlands (Mitchell-Bruker et al., 2001). At the same time that WCA-3B was being drained, S-332B was overflowing, allowing undesirable direct discharges to ENP during rain events. In January and February of 2000, S-332D pumping was concurrent with the opening of S-334. However from July through October, under the ISOP 2000 wet season operations, S-332D was operated to receive flows from S-335 and S-331. In essence this wet season operation used S-332D to route flood waters from WCA-3B, the Pennsuco Wetlands, NESS and the 8.5 SMA into ENP.

2.2.2.2 ISOP 2001 January 2001-June 2001

ISOP 2001 was formulated and implemented in January 2001. The plan supported the same objectives as ISOP 2000. Plan components were similar except that WCA-2A schedule modifications that were made in ISOP 2000 were removed. WCA-3A schedule modifications were also included, removing additional water later in the dry season. S-12D remained open during the breeding season and the S-332B impoundment and pumps were in place. A summary of the ISOP operations from June 2000 to May 2001 from Knight et al (2002) states:

- S-333 contributed 67,000 acre-feet of water to NESS whereas the upper reach of the L-31N canal between S-335 and G-211 drained 189,000 acre-feet of water from NESS and the lands to the east of the canal.

- The G-3273 water level constraint on operations at S-333 along with the presence of the L-67 Extension levee remain as barriers to the restoration of hydrologic conditions in NESS. Regulatory releases through the S-12 structures compound the effects of these impediments as large volumes of water are confined to the western portion of Shark Slough.

- The ISOP lowered the operational criteria at every structure along the L-31N and C-111 canals from G-211 to S-18C relative to Test 7 Phase I of the EWD program. While flows to the SDCS were high, despite the below average rainfall, most of this additional water was derived from WCA-3B and NESS.

- The L-31N canal above G-211 drained water from NESS for the entire study year. In combination with S-335, G-211 was utilized to convey water from WCA-3B and NESS toward the C-111 basin. Operational changes under the ISOP resulted in the largest volume of water drained during the wet season by the upper reach of the L-31N canal since 1993.

- The S-331 pump station continued to be operated to provide flood protection to the 8.5 Square Mile Area despite its original authorization as a water supply structure for the SDCS. These operations exacerbate the dry conditions in the northern Rocky Glades and NESS and compromise the level of flood protection in the C-111 basin.

- Operations at the newly constructed S-332B pump station were focused on providing flood protection rather than rehydration of the Rocky Glades region of ENP. No water was pumped during the dry season and therefore no extension of the hydroperiod in the region of the Rocky Glades was observed.

- On two occasions totaling 27 days, pumping at S-332B was great enough to overflow the detention area and cause direct surface water discharges to ENP. Overflow into the Park is an undesirable condition because of the introduction of nutrient-rich water into a nutrient-poor marsh, an ecological system that is accustomed to low-nutrient inflows.

- The S-332 D pump station provided significant amounts of water to Taylor Slough during the wet season of 2000 and reduced seepage losses toward the L-31 W canal by maintaining canal levels near to the water levels in the marsh.

- The lower C-111 canal received a large portion of the water that was drained from the upstream canal reaches. It was the only canal reach during the study period to constantly recharge the adjacent marsh.

- Despite significantly less rainfall during the 2000-2001 study year compared to the previous study year, flows through S-18C into the Eastern Panhandle were greater due to operations under the ISOP. The wet season flow at S-18C was greater than the total wet season discharges through the S-12 structures into Shark Slough.

2.2.3 IOP (June 2002-December 2002)

The Interim Operations Plan (IOP) is described in the FEIS (USACOE, 2002). The IOP consists of structural and operational components. The structural components include removal of the southern four miles of the L-67 extension, construction of the S-356 pump station, construction of the S-332C pump stations, construction of S-332B, S-332C, and S-332D reservoirs, and construction of connector reservoirs between S-332B, S-332C and S-332D reservoirs. At the time of this writing, the connector reservoirs and S-356 pump station are not operating due to permit and land acquisition delays.

Two different modes of water management operation for the SDCS (SDCS) have been described for the IOP (Column 1 and 2 of Table 5). The first mode is "No WCA-3A regulatory releases to SDCS" in which L-31N canal would be maintained at Test 7 Phase I levels when there are no WCA-3A regulatory releases. Citing a concern that maintaining L-31N canal at ISOP levels would impact ENP resources, a "No WCA 3A regulatory releases to SDCS" operation was proposed that essentially reverts back to Test 7 Phase I canal levels when no regulatory releases are routed to SDCS. The second mode of operations is "WCA-3A regulatory releases to SDCS" operation in which L-31N canal would be lowered to minimize potential flood impacts in SDCS and at the same time, provide a downstream gradient to move WCA 3A regulatory releases through S-333 and S-334. The intended purpose of routing regulatory releases from WCA-3A to SDCS with lower canal stage in L-31N was to provide sufficient water to be delivered via S-332B to the habitats of sparrow sub-populations E and F and at the same time, minimize potential flooding impacts to the 8.5 SMA and agricultural areas adjacent to L-31N canal. Although the initial ISOP emergency action was taken in response to concerns about the endangered CSSS, the IOP operations were designed to increase flood protection capacity in order to maintain the existing (ISOP) level of flood protection.

Under ISOP the S-332B pump station and 160 acre S-332B reservoir were constructed. A weir, located on the western side of the S-332B reservoir was used to route excess water from the SDCS to ENP. The IOP includes an additional 240 acre S-332BN reservoir at the S-332B structure, increasing capacity from 160 acres of retention to 400 acres. A new pump station (S-332C) and seepage reservoirs along the L-31N Canal was added under IOP to supplement the capacity of the existing pump stations, S-332B and S-332D, to lower canal and groundwater levels in advance of significant storms. The pump stations draw water out of the canal and pump the water into reservoirs along the eastern boundary of the Park. Much of the pumped water returns to the canal through groundwater seepage. During non-storm conditions, the pump stations should be operated at reduced capacity to maintain a water depth in the reservoirs necessary to create a continuous hydraulic ridge along the Park boundary for seepage control. This hydraulic ridge concept was developed in the authorized C-111 Project. The pumping should be adjusted seasonally to maintain the desired water conditions in sparrow habitat within the Park conducive to breeding and habitat maintenance, and marsh operations will be implemented to meet this objective.

Construction of the previously authorized pump station S-356 in the Tamiami Canal is also included so that it can be used to return seepage from the northern reach of the L-

31N Canal to NESS. The S-356 and S-332B and S-332C pump stations were built as interim structures, along with associated seepage reservoirs, by June 2002 for use in protecting sparrow habitat during the upcoming wet season. S-356 pump station has been constructed but is not operational. Alternative 7R also includes the removal of the southern four miles of L-67ext Levee and Canal.

The IOP record of decision was signed in June 2002. In April 2002 WCA-3A was below schedule and the dry conditions in South Dade necessitated water supply operations. Before the ISOP began in December 1999, the S-335 structure was operated as a water supply structure and historically remained closed during the wet season. Under ISOP, the S-335 was initially used to route water diverted from WCA-3A via S-151 when the S-12 structures were closed. The S-335 operation allowed regulatory flows that previously were routed through the S-12 structures to the northwestern side of ENP to be routed to the southeastern side of ENP. Water levels in the eastern canals were lowered to accommodate this operation. When the S-12's were open, S-335 was closed. In 2002, under IOP, the S-335 structure was used throughout the wet season, even though the S-12 structures were also open. This new wet season operation allowed operators to move large amounts of flood water from the northern end of the system into the southeastern end of ENP, while at the same time keeping water levels in the eastern canals at lower levels to provide flood protection to Dade County.

Under the IOP water is no longer delivered directly to Taylor Slough via S-332. Instead, water is pumped into the S-332D detention basin high-head cell. Water from the high head cell spills into the downstream detention basin, and also seeps through the underlying limestone to the L-31W canal. Water from L-31W canal travels southward towards Taylor Slough and the southeastern marl prairies, losing part of its flow to the aquifer below.

Table 5. IOP Alt7R operations

	No WCA-3A Regulatory Releases to SDCS or Shark Slough	WCA-3A Regulatory Releases to SDCS
Regulation Schedule	Deviation schedule for WCA-3A as specified by USACOE including raising Zone D to Zone C from Nov 1 to Feb 11. No deviation in WCA-2A regulation schedule.	Deviation schedule for WCA-3A as specified by USACE including raising Zone D to Zone C from Nov 1 to Feb 11. No deviation in WCA-2A regulation schedule.
S-343 A/B and S-344	Closed Nov 1 to July 15 independent of WCA-3A levels.	Closed Nov 1 to July 15 independent of WCA-3A levels.
S-12 A/B/C/D	S-12A closed Nov 1 to Jul 15; S-12B closed Jan 1 to Jul 15; S-12C closed Feb 1 to Jul 15; S-12D no closure dates. Follow WCA 3A regulation schedule after Jul 15.	S-12A closed Nov 1 to Jul 15; S-12B closed Jan 1 to Jul 15; S-12C closed Feb 1 to Jul 15; S-12D no closure dates. Follow WCA 3A regulation schedule after Jul 15.

	No WCA-3A Regulatory Releases to SDCS or Shark Slough	WCA-3A Regulatory Releases to SDCS
	Note: If closure requires regulatory releases to SDCS then switch to operations for regulatory releases to SDCS.	
S-333: G-3273 < 6.8' NGVD Degrade the lower portion of the L-67 extension	55% of the rainfall plan target to NESRS and 45% through the S-12 structures	55% of the rainfall plan target to NESS, plus as much of the remaining 45% that the S-12s can't discharge to be passed through S-334; and subject to capacity constraints, which are 1350 cfs at S-333, L-29 maximum stage limit, and canal stage limits downstream of S-334.
S-333: G-3273 > 6.8' NGVD	Closed	Match S-333 with S-334 flows
L-29 constraint	9.0 ft	9.0 ft
S-355A&B	Follow the same constraints as S-333. Open whenever gradient allows southerly flow.	Follow the same constraints as S-333. Open whenever gradient allows southerly flow.
S-337	Water Supply	Regulatory releases as per WCA-3A deviation schedule.
S-151	Water Supply	Regulatory releases as per WCA-3A deviation schedule.
S-335	Water Supply Allow releases through S-335 if there is downstream capacity consistent with pre-ISOP operations. “Downstream capacity” would not include capacity created by pumping at S-332B or S-332D and not trigger opening S-18C at 2.6. Note: It is recognized that under these conditions operations of S-335 would be infrequent.	When making regulatory releases through S-151, match S-335 outflows with inflows from S-151 and S-337
S-334	Closed	Pass all or partial S-333 flows Depending on stage at G-3273 (see note 3)
S-338	Open 5.8 Close 5.5	Open 5.8 Close 5.4
G-211	Open 6.0 Close 5.5	Open 5.7 Close 5.3

	No WCA-3A Regulatory Releases to SDCS or Shark Slough	WCA-3A Regulatory Releases to SDCS
S-331	Angel's Criteria	Angel's Criteria
S-332B Note 1: There will be two 125-cfs pumps and one 75-cfs pump directed to the second detention basin. The remaining two 125-cfs pumps will be directed to the first detention basin. If possible, the 75-cfs pump will be designed so that it can be directed to either basin. Note 2: A new indicator will be established for Subpopulation F and a new gauge will be installed about ½ mile west of the weir on the western edge of the retention area. Pumping will cease after 180 days of above ground hydroperiod at the new gauge during a year that runs from July 15th to July 14th. After water levels recede below ground, pumping can be resumed at a rate that maintains water elevations below ground at the gauge until the beginning of the next year.	Pumped up to 250 cfs* from Jun through Feb; and 125 cfs from Mar through May. On 5.0 Off 4.7** *This pumping rate is based on the assumption that there will be no overflow into the Park. If there is overflow into the Park, the pumping rate will be adjusted. **If, after the first 30 days of operation, there is no observed drawdown at the pump, this stage level will be raised to 4.8	Pumped up to 250 cfs* from Jun through Feb; and 125 cfs from Mar through May. On 4.8 Off 4.5 *This pumping rate is based on the assumption that there will be no overflow into the Park. If there is overflow into the Park, the pumping rate will be adjusted to eliminate overflow.
S-332B Seepage Reservoir	400 acres with no overflow to the west	400 acres with with no overflow to the west
S-332D	Pumped up to 500 cfs from Jul 16 (or the end of the breeding season, as confirmed by FWS) to Nov 31; 325 cfs from Dec 1 to Jan 31; and 165 cfs* from Feb 1 to Jul 15. Meet Taylor Slough Rainfall formula (No L-31W constraint)	Pumped up to 500 cfs from Jul 16 (or the end of the breeding season, as confirmed by FWS) to Nov 31; 325 cfs from Dec 1 to Jan 31; and 165 cfs* from Feb 1 to Jul 15. Meet Taylor Slough Rainfall formula (No L-31W constraint)

	No WCA-3A Regulatory Releases to SDCS or Shark Slough	WCA-3A Regulatory Releases to SDCS
	On 4.85 Off 4.65 *New information will be sought to evaluate the feasibility of modifying the 165 cfs constraint	On 4.7 Off 4.5 *New information will be sought to evaluate the feasibility of modifying the 165 cfs constraint
S-332	Closed	Closed
S-175	Closed	Closed
S-194	Open 5.5 Close 4.8	Operated to maximize flood control discharges to coast Open 4.9 Close 4.5
S-196	Open 5.5 Close 4.8	Operated to maximize flood control discharges to coast Open 4.9 Close 4.5
S-176	Open 5.0 Close 4.75	Open 4.9 Close 4.7
S-177	Open 4.2 (see S-197 open) Close 3.6	Open 4.2 (see S-197 open) Close 3.6
S-18C	Open 2.6 Close 2.3	Open 2.25 Close 2.00
S-197		

S-197 open and criteria remains consistent with Test 7 Phase I criteria for S-177
Use S-333/334 before S-335

2.2.4 Pre-storm operations

The ISOP was revised in the March 2000 Environmental Assessment (USACOE, 2000) to include flood control operations and pre-storm operations. The ISOP operations in the March 2000 EA “seek to lower canal levels during the wet season and allow for higher water levels during the dry season. These operations also take into account real-time field conditions as measured in groundwater wells and forecasted storm events” to lower water levels in canals in order to improve flood protection capability in Dade County. Increased capability to draw down groundwater levels when a significant storm is predicted is obtained by pumping water out of the canal and pumping the water into reservoirs along the eastern boundary of ENP. The target canal levels (Table 6) are 1.5 to 3.0 feet below the design levels for a 1-10 storm event, as much as 2.0 ft. below Test7I levels, and 0.5 –1.0 feet below normal IOP canal levels. Paradoxically, the pre-storm water levels are the same as the water supply levels for two of these reaches, signaling dry conditions that require water to be brought into the basin from upstream. These pre-storm operations are also included in the IOP.

Table 6. Pre-storm draw-down canal levels compared to optimum C-111, Test 7I, ISOP/IOP Column 1 and Column 2.

Canal	Reach	Optimum Design Level* (ft)	C-111 1-in-10 storm level (ft)	Test 7I level (ft)	ISOP and IOP Col 2 level (ft)	IOP Co1 1 level (ft)	Pre-storm level (ft.)
L-31N	G-211 to S-331	(5.0)**	Not specified	6.0	5.8/6.0 (wet/dry)	5.7	4.0
L-31N	S-331 to S-176	5.5	7.2-6.0	5.0	4.7	5.0	4.0
C-111	S-176 to S-177	4.5	5.5-4.3	4.2	4.0	4.2	3.0
C-111	S-177 to S-18C	2.0	4.3-3.8	2.6	2.25	2.6	2.0

* When water levels are 1.5’ below optimum, water is transferred into the reach for water supply.
** This design optimum was for the reach between US-41 and S-331, before G-211 was built to reduce seepage losses from NESS.

Pre-storm operations are implemented 24-72 hours in advance of tropical storm force winds. For other than named events, the SFWMD monitors the antecedent conditions and can recommend initiation of pre-storm operations if these conditions indicate a strong likelihood of flooding. The Corps will review the data, advise ENP and FWS of the conditions, consult with the Miccosukee Tribe and make a decision on pre-storm implementation. In the 16-month period from August 2001 to December 2002, pre-storm operations have been implemented 8 times. Three of those incidents were associated with named storms, 5 pre-storm incidents were initiated based on the SFWMD recommendations. Pre-storm operations occurred twice in August 2001 and twice in October 2001.

3 Analysis of Hydrologic Impacts of ISOP/IOP Operations

An examination of the hydrologic effects of any given set of operational rules in a system as complex as the C&SF Project is a difficult undertaking. Rainfall conditions are extremely variable, both temporally and spatially. Monitoring networks are, at best, incomplete. The operational rules themselves are ever changing and rapidly evolving. It is therefore essential to focus the analysis on areas where one expects changes, and then attempt to deduce from the modeling and observed data, what those changes were.

This section is organized as follows. First, we examine the operational records to determine the functional differences between ISOP and IOP. Next, we compare those observed differences to the predicted operations in the EIS. Lastly, we analyze the observed data to ascertain the likely results of IOP operations on the natural system, focusing on ENP, WCA-3, and the Pennsuco wetlands.

3.1 ISOP and IOP Implementation

The IOP contains two modes of operations depending on whether or not regulatory releases from WCA-3A are being routed into the SDCS. The IOP dictates that WCA-3A regulatory releases be routed into the SDCS as mitigation for restricting the operation of the S-12 structures. Flows through the S-12 structures, particularly the western most, S-12A and S-12B, discharge water directly into the CSSS sub-population A located on the western edge of Shark Slough. Under the IOP, flows through the S-12 structures are limited beginning on November 1, when S-12A must be closed and ending on July 15, generally considered the end of CSSS breeding season. According to the IOP agreement, during the time when S-12 operations are restricted, regulatory flows from WCA-3A can be routed into the SDCS, provided the canal system in south Miami-Dade has the capacity to accept the additional water. As further mitigation for this operation, canal levels in the SDCS are operated at lower water levels to provide additional storage for the WCA-3A inflows. The additional flood protection provided by the lower water levels is offset by the increase in flooding potential caused by inter-basin transfer of water from WCA-3A to SDCS.

The two modes of operations are commonly referred to as “Column 1” and “Column 2” operations, since that is the way they are listed in the operations summary table in the IOP FEIS. Column 1 was to be used when S-12 flows are not restricted; Column 2 operations are used when S-12 flows are restricted and water levels in WCA-3A are above regulation stages.

From the beginning of IOP operations in July 2002, there were disagreements about interpretation of when Column 1 and Column 2 regimes should apply. The record of decision (ROD) came on July 2, 2002. ISOP operations, or Column 2 operations, continued through October 2002. The South Florida Water Management District (SFWMD) claimed that, so long as S-334 was open, regardless of the volume, Column 2 would apply. The counter contention was that S-334 had to be passing a substantial amount, resulting in tangible and significant benefits in WCA-3A, before Column 2 would apply. Another source of disagreement was whether or not to remain in Column 2 even when the S-12 structures were fully open. SFWMD and USACOE contended that Column 2 operations should not cease until the volume that was held in WCA-3A between the time when water levels exceeded regulation stage and July 15 was passed into the SDCS. The counter claim was that this was not how it was modeled or described in the EIS, and was most certainly not the intention of IOP. A third issue was over whether Column 2 applies in Zone E1. This zone was added during ISOP to reduce WCA-3A stages, but is not above the regulation stage for WCA-3A. These disagreements remain, by and large, unresolved. In summary, regardless of the settlement of these debates, an accurate observation would be that operations during the 2002 wet season did not differ functionally from ISOP operations. In order to circumvent the controversial definitions, this analysis has lumped ISOP and IOP operations together

The system entered Column 1 in late October 2002 and remained until March 20, 2003 when S-334 was operated to relieve high water in WCA-3A. On July 15, 2003, when S-12 restrictions were over, the system remained in Column 2 operational mode. It was not until August 8, 2003 that the USACOE decided sufficient flows had been passed into the SDCS from WCA-3A to justify the implementation of Column 1 operations.

Table 7 summarizes the transitions and schedule of the two modes of operations along with significant dates. The time period between the start of IOP operations in July 2002 and the end of the 2003 wet season consists of 68 weeks. Overall, operations have been under the Column 2 schedule for 33 weeks, or 48 percent of the time. Of greater significance is that of those 68 weeks, 30 of them have been during the wet season with no S-12 flow restrictions. Of these 30 weeks we have been in Column 2 operations for 15 weeks, or half the time.

Table 7. IOP Column 1 vs. Column 2 Operations

Date	Comment	No. of Weeks	Colum1 / Column 2
July 2, 2002	IOP Record of Decision		
July 15, 2002	S12 Flow Restrictions End	**2**	**Column 2**
Oct 7, 2002	First Column 1 Operations Begin	**12**	**Column 2**
Oct 31, 2002	End of 2002 Wet Season S12 Restrictions Begin	**3**	**Column 1**
March 20, 2003	Column 1 Operations End – Column 2 Operations Begin	**20**	**Column 1**
June 1, 2003	Beginning of 2003 Wet Season	**10**	**Column 2**
July 15, 2003	S12 Flow Restrictions End	**6**	**Column 2**
August 8, 2003	Column 2 Operations End -- Column 1 Operations Begin	**3**	**Column 2**
Oct 31, 2003	End of 2003Wet Season S12 Flow Restrictions Begin	**12**	**Column 1**

3.2 A Regional Perspective

Given the complexity of the C&SF Project and the extent of the operational changes in the ISOP/IOP relative to previous operations, it was expected that the hydrologic response would also be complex. The initial difficulty presented is finding some starting point, some way of pointing out where possible changes might have occurred. This analysis begins with examination of the regional depths and water budgets; their use is to identify potential areas of interest in which to focus the evaluation rather than to provide a definitive analysis.

3.2.1 Water Depths

Water depth maps of the study area were made by subtracting grids of measured water levels at monitoring sites from grids of measured topography. In these analyses we use water level information obtained from the USGS, the USACOE, the SFWMD, and ENP . The water level surfaces were generated in the software package Surfer™ using a nearest neighbor interpolation algorithm. The topographic data was obtained from the USGS, and is based on their high accuracy topography data collection project using the Airborne Height Finder at 400 meter grid spacing. The two surfaces were then subtracted to obtain an estimate of the spatial distribution of water depth.

Figures 3 and 4 are the composites of hydrologic year average water depths for the Test 7 and ISOP/IOP periods. Comparing the Test 7 and the ISOP/IOP water depths, without considering rainfall, one would conclude that ISOP/IOP water depths are generally considerably drier than Test 7 average water depths. Based on a cursory review of these maps by experienced hydrologists, it appears that WCA-3A and -3B are significantly drier, as are western Shark Slough and NESS. It is difficult to see significant differences in the Rocky Glades, and in the lower C-111 area, but it does appear that Taylor Slough is somewhat wetter in the vicinity of SR 9336.

It is, of course, difficult to draw conclusions from these images, but they do provide a starting point. First, it is clear that the differences in rainfall contribute significantly to the water level differences, but this cannot be the only reason for the disparity. The depth differences from year to year appear to change on a spatial level and are not uniform in magnitude. This suggests that the effect of rainfall must be isolated before an unbiased examination of the effects of operations can be completed.

One way to estimate the impact of rainfall is to compare water depths during periods of similar rainfall, both within Test 7 and ISOP/IOP, and between the two operative regimes. Within the Test 7 period, the hydrologic years of 1996-97 and 1998-99 have similar rainfalls, 51.7 and 53.2 inches, respectively. Comparison of the water depth maps for these years reveals a similar distribution of water depths (Figures 2(B) and 2(D)), although it appears that water depths in Shark Slough and the western side of ENP are drier during the 1998-99 hydrologic year. A similar within-Test 7 comparison can be made between the 1995-96 and 1997-98 hydrologic years. Again, the average water depth distributions are similar, but there are slight differences in that the western marl prairies are slightly wetter in 1997-98 than in 1995-96. Taylor Slough was slightly wetter in 1997-98 than in 1995-96. These slight differences in water depth distribution can be used as a yardstick for Test 7 to ISOP/IOP comparisons.

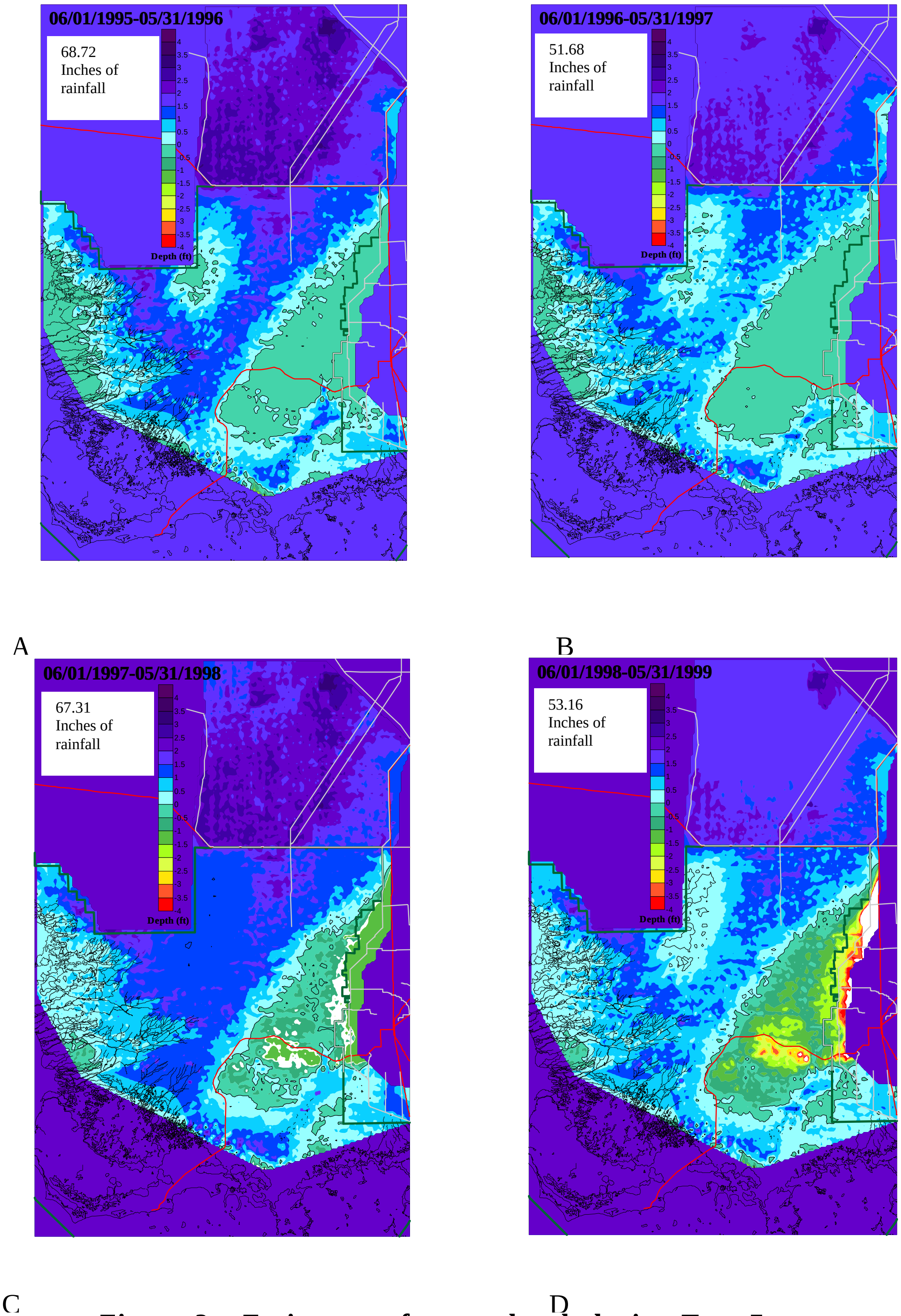
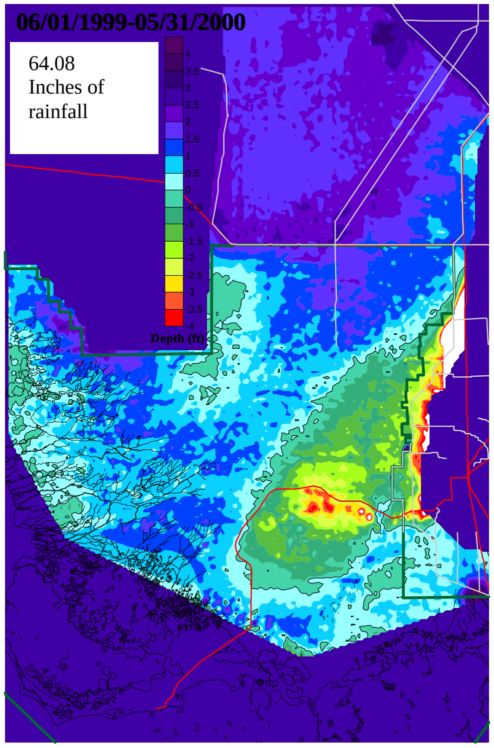


Figure 3. Estimates of water depth during Test 7.



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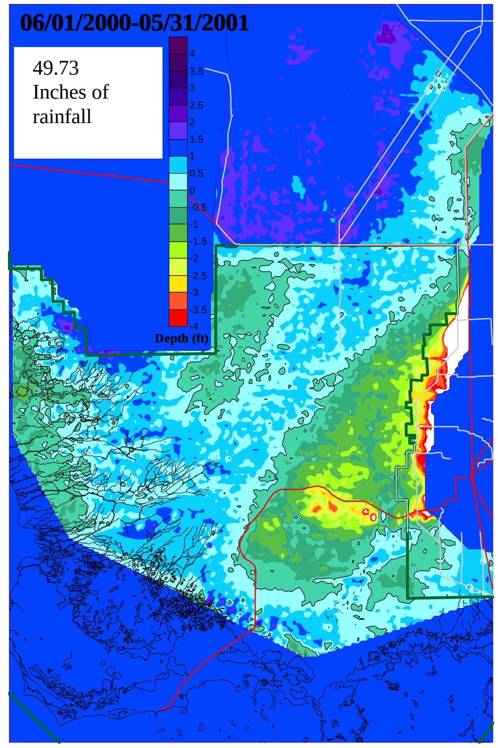

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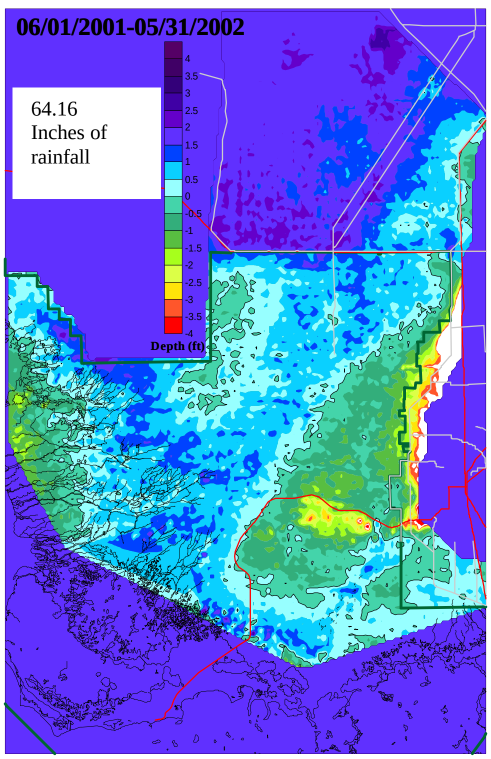

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Figure 4. Estimates of water depths during the ISOP/IOP period.

The 1996-97 and 2000-01 hydrologic years have similar rainfalls (51.7 and 49.7 inches, respectively), and are a good source for seeking out potential operational effects. Unlike the within Test 7 period comparisons, these water depth distributions are very different. These differences are most pronounced in WCA-3 and the Shark Slough drainages. Drier conditions prevail throughout most regions during the ISOP/IOP period. While the intent of providing drier conditions for the Western habitat of the CSSS seems to be met in 2000-01, the operations tended to dry the entire region, including NESS, WCA-3A, WCA-3B, and the Pennsuco wetlands. Moreover, the eastern sparrow habitats do not appear to have met the ISOP goal of providing wetter conditions. Although there is no significant drying pattern in the Rocky Glades, there is also no significant wetting in these areas.

One can further test these observations by examining similar wet season and dry season water depth maps for periods which experienced comparable rainfall. Figures 5 and 6 are the composites of average wet season water depths for the Test 7 and ISOP/IOP periods. Within Test 7 the rainfalls for 1996 and 1998 wet seasons are similar, with 36 and 35.2 inches, respectively, although the water is deeper throughout the region in 1998. This difference can be explained by the difference in May rainfall, which is the lead-in to the wet season, although it is not included in the wet season rainfall total. In 1996, the wet season actually started with 8 inches of rainfall in May, whereas in 1995 the May rainfall was only 3.6 inches. The 1995 and 1999 wet seasons were also similar with 52.5 and 52.0 inches of rain. Again, comparison of these depth distributions shows a similar but drier pattern in the later year, with shallower water depths in the western marl prairies southern Shark Slough, NESS, and the Rocky Glades. The drier conditions in 2000 can be attributed to antecedent conditions, given the much lower dry season rainfall in 1998-99 (18 inches) as compared to 25 inches in 1994-95.

The 1996 and 2000 wet season water depth maps can be used to compare between Test 7 and ISOP/IOP wet seasons, with rainfalls of 36 and 37.4 inches, respectively. Antecedent conditions for 1996 were significantly wetter than 2000. The dry season rainfall for 1995-1996 was 16.3 inches compared to 12.1 inches for 1999-2000. The May rainfall for 1996 was 7.7 inches. Given these differences in antecedent conditions one might expect to see shallower water depths, but the higher rainfall in 2000 relative to 1996 is expected to partially offset these differences. Comparing the two water depth maps (Figure 5(B) and 6(B)), it can be seen that conditions are much drier in many areas in 2000. One would expect that western and central Shark Slough would be drier, as that was an objective in IOP. However, in addition to Shark Slough, WCA-3A and WCA-3B are also much drier in 2000, as are the Rocky Glades.

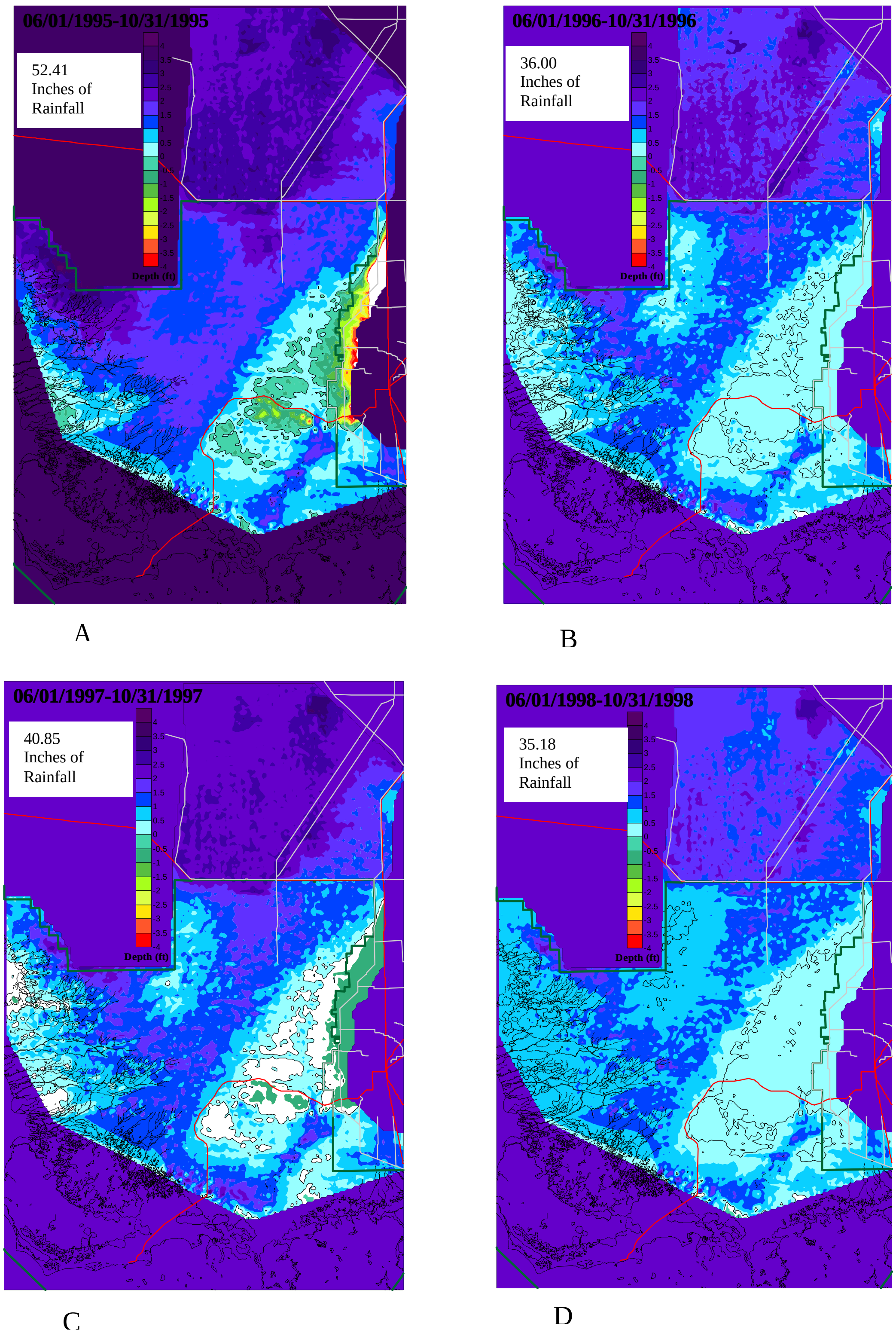

Figure 5. Wet season depths from selected Test 7 operation years.

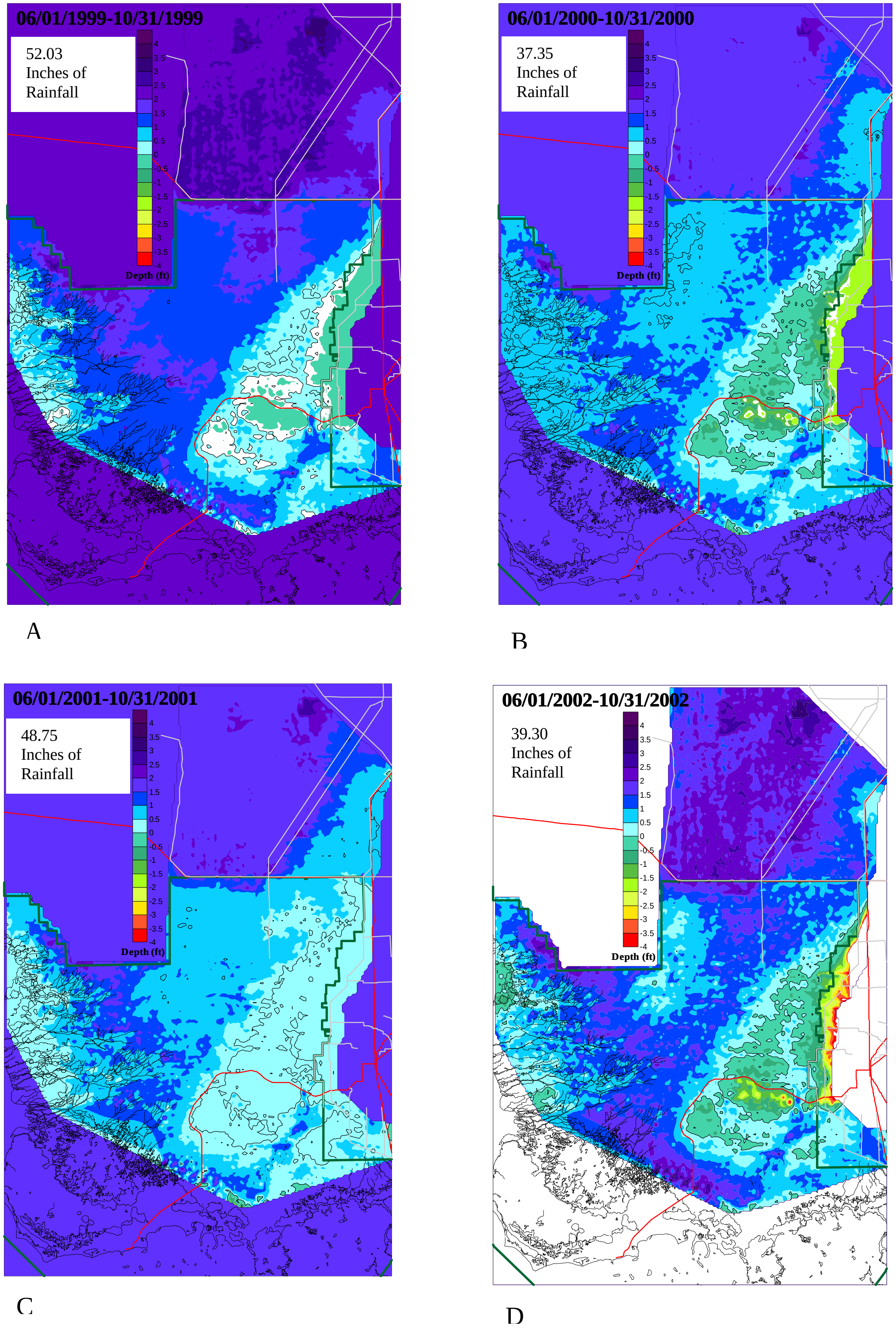

Figure 6. Wet season water levels during the ISOP/IOP period.

An additional comparison between the 1997 and 2002 wet seasons can be made, given the similar rainfalls, 40.9 and 39.3 inches, for those periods. The antecedent conditions for these two years are also very similar, with 15.7 inches of rainfall in 1996-97 dry season and 15.4 inches for 2001-02. The 1997 May rainfall was 4.8 inches, which is similar to the 5.3 inches. of May 2002. Because the antecendent conditions are also very similar for these two years, this comparison provides a better opportunity to isolate the effects of operations. In addition, this comparison provides an opportunity to compare IOP, which is the current operation, to Test 7. For this comparison (Figures 6(C) and 6(D)), most of ENP has similar water depths in both years, however central Shark Slough, Taylor Slough, and the Taylor Slough headwaters are drier under the IOP operations. As in the previous comparisons, WCA-3A and WCA-3B are drier under the IOP operations. In addition to these two comparisons of similar rainfall periods, it is useful to note that even with 48.8 inches of wet season rainfall in 2001, WCA-3 and Western ENP are drier than in 1996 (36-in. rain) and 1998 (35-in. rain).

While this analysis is only qualitative, it offers the opportunity to identify probable effects of the operational regimes upon which to focus the more detailed quantitative investigation. Overall, it would appear from these comparisons that WCA-3A, WCA-3B, and the Pennsuco wetlands are drier under ISOP/IOP than under Test 7. Taylor Slough, near SR9336 appears wetter, but it is difficult to determine the effects in the Rocky Glades and Eastern Panhandle area. Subsequent sections of this report analyze the hydrologic data in greater detail to determine whether these initial observations are, in fact, supported by the observed hydrologic data.

3.2.2 Canal Water Budgets

Just as the averaged water depth maps provide some insight into the response of the wetlands, canal water budgets can provide insights concerning the response of the managed system to the operational rules and rainfall events. Figures 7 through 11 are the canal water budgets for the C&SF Project structures in the vicinity of ENP prior to ISOP/IOP operations, while Figures 12 through 15 are those observed during ISOP/IOP operations. These water budgets are constructed as follows. Data for all structures controlling flow into and out of a section of canal was collected in the form of total annual flow volumes, as reported by SFWMD's hydrological database (DBHYDRO). Net seepage out of the park (shown in red) was then estimated by subtracting the structure inflow volumes from the outflow volumes.

In comparing and contrasting these eight graphics, several features stand out as significant. First, there are large changes in the magnitude of the S-12 discharges, as the ISOP/IOP flows appear to be considerably reduced. This is consistent with lower water levels in western Shark Slough, but will require further investigation to explain the apparent effects in WCA-3A and 3B. It also appears that the inflows into NESS appear similar from year to year, almost independent of rainfall.

Another point of interest is S-335, which is the outlet of L-30, the canal along the eastern side of WCA-3B and the western side of the Pennsuco wetlands. Flows appear to increase during ISOP/IOP when compared to prior years, even as rainfall decreases.

Similarly, outflow at S-338 appears to increase significantly in the above average ISOP/IOP rainfall years when compared to prior operations. This would suggest that S-335 and upper L-31N operations need further examination.

S-331 and G-211 flow volumes are similar in both periods, but do exhibit inter-annual variability. These flows are the primary inflow to lower L-31N canal. The operations and resultant effects on this reach of canal have received intense scrutiny. Past investigations (Van Lent et al, 1993; Van Lent et al, 1999) have pointed to operations of this canal as a primary cause of reduced water levels along the eastern side of ENP. Others are concerned that operations of this canal have resulted in adverse flooding effects. The ISOP/IOP implementation resulted in new structures (S-332B, S-332C) and revised operations (S-332D) in an attempt to address these concerns. Thus, detailed analysis of the effects in this reach of L-31N is definitely needed.

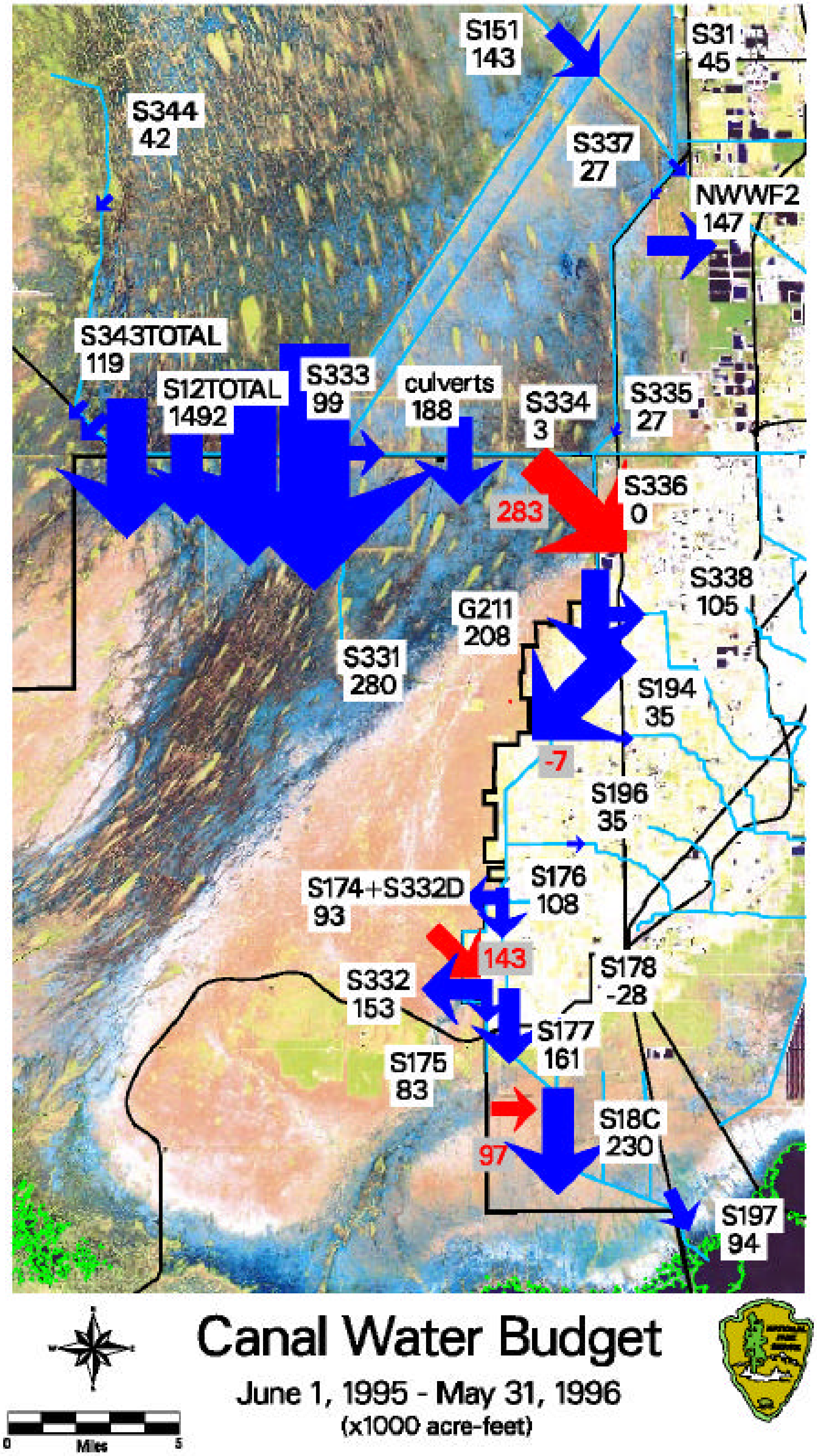

Figure 7. Canal Water Budget June 1, 1995 – May 31, 1996

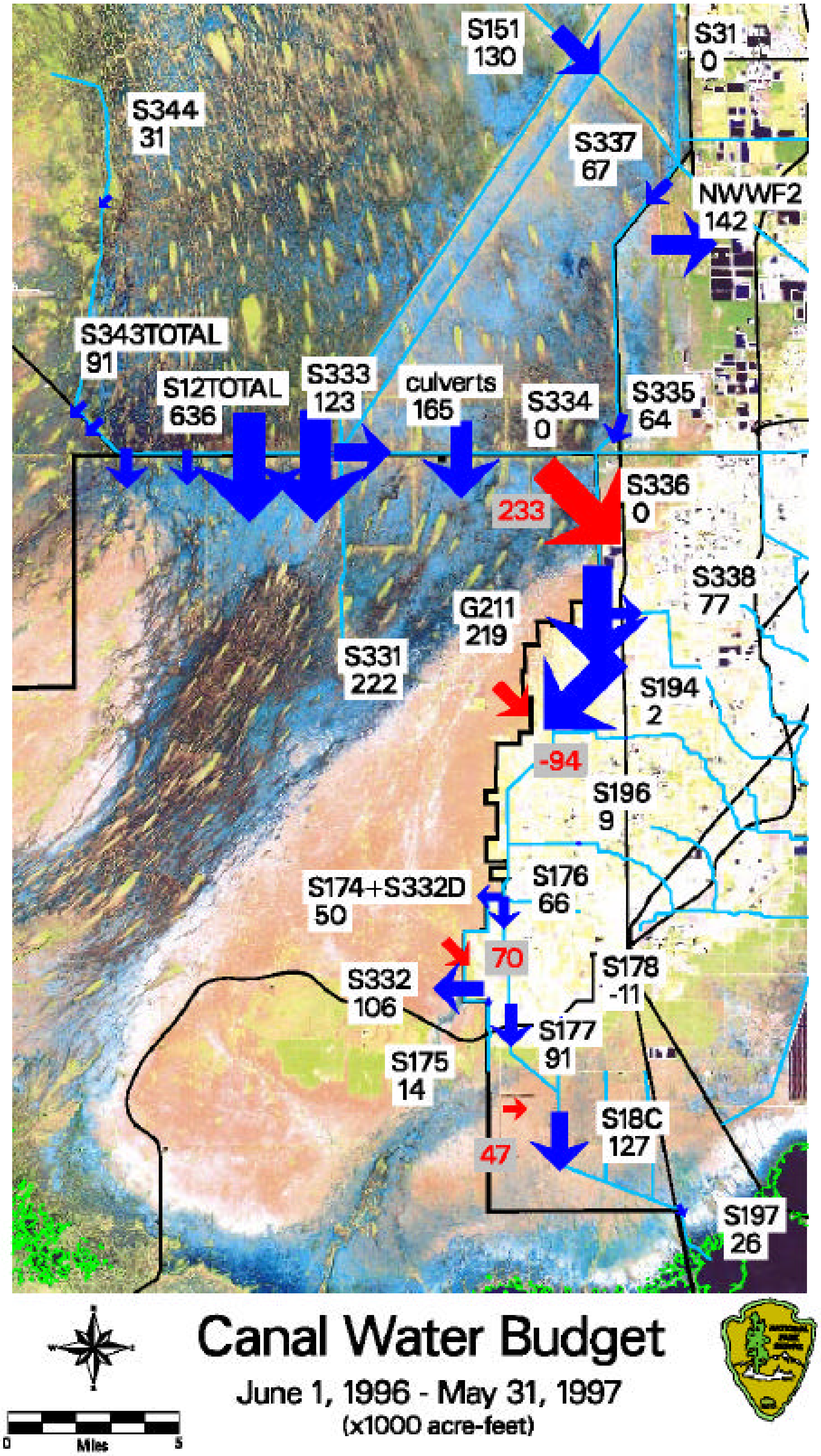

Figure 8. Canal Water Budget June 1, 1996 – May 31, 1997

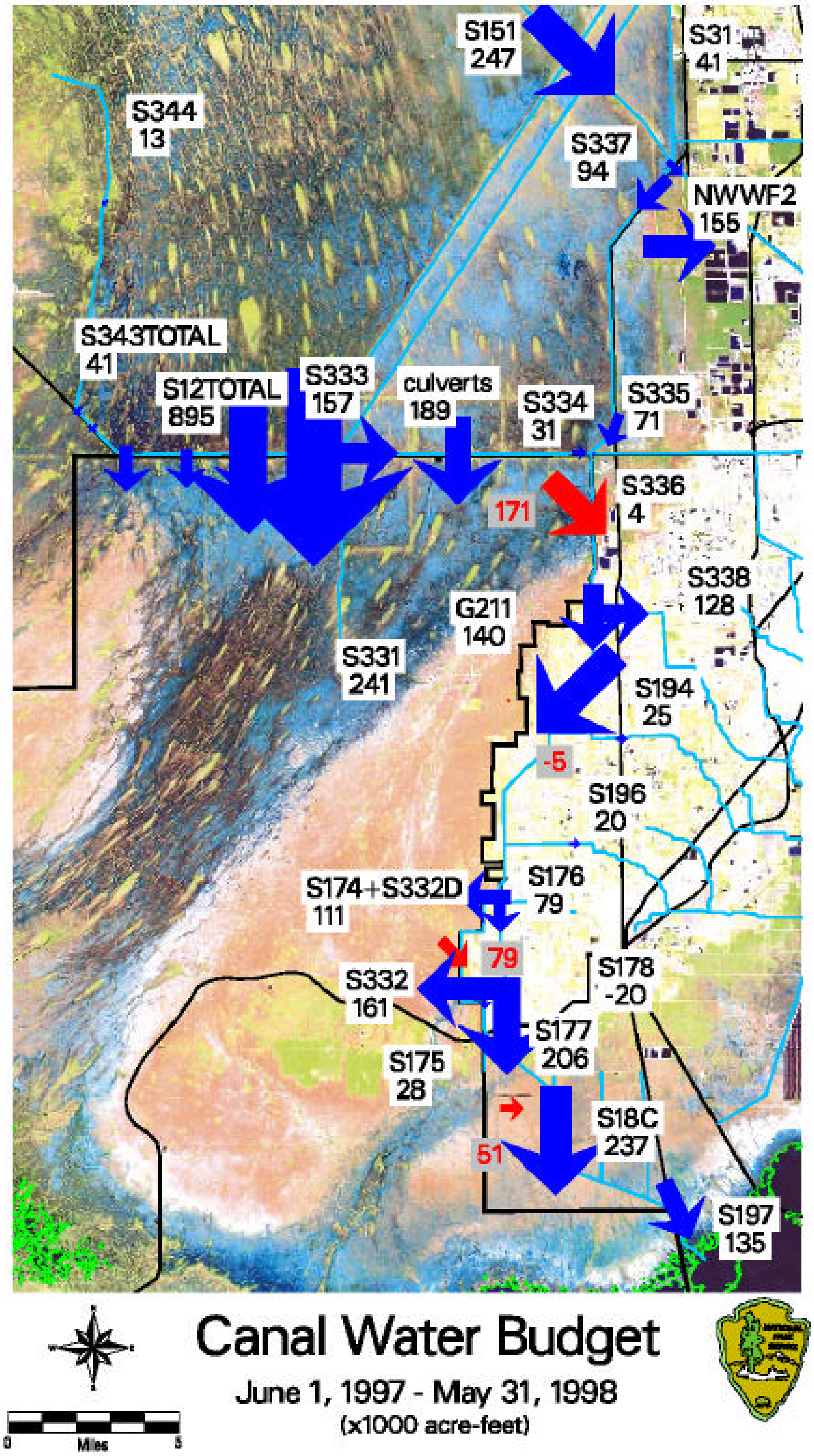

Figure 9. Canal Water Budget June 1, 1997 – May 31,

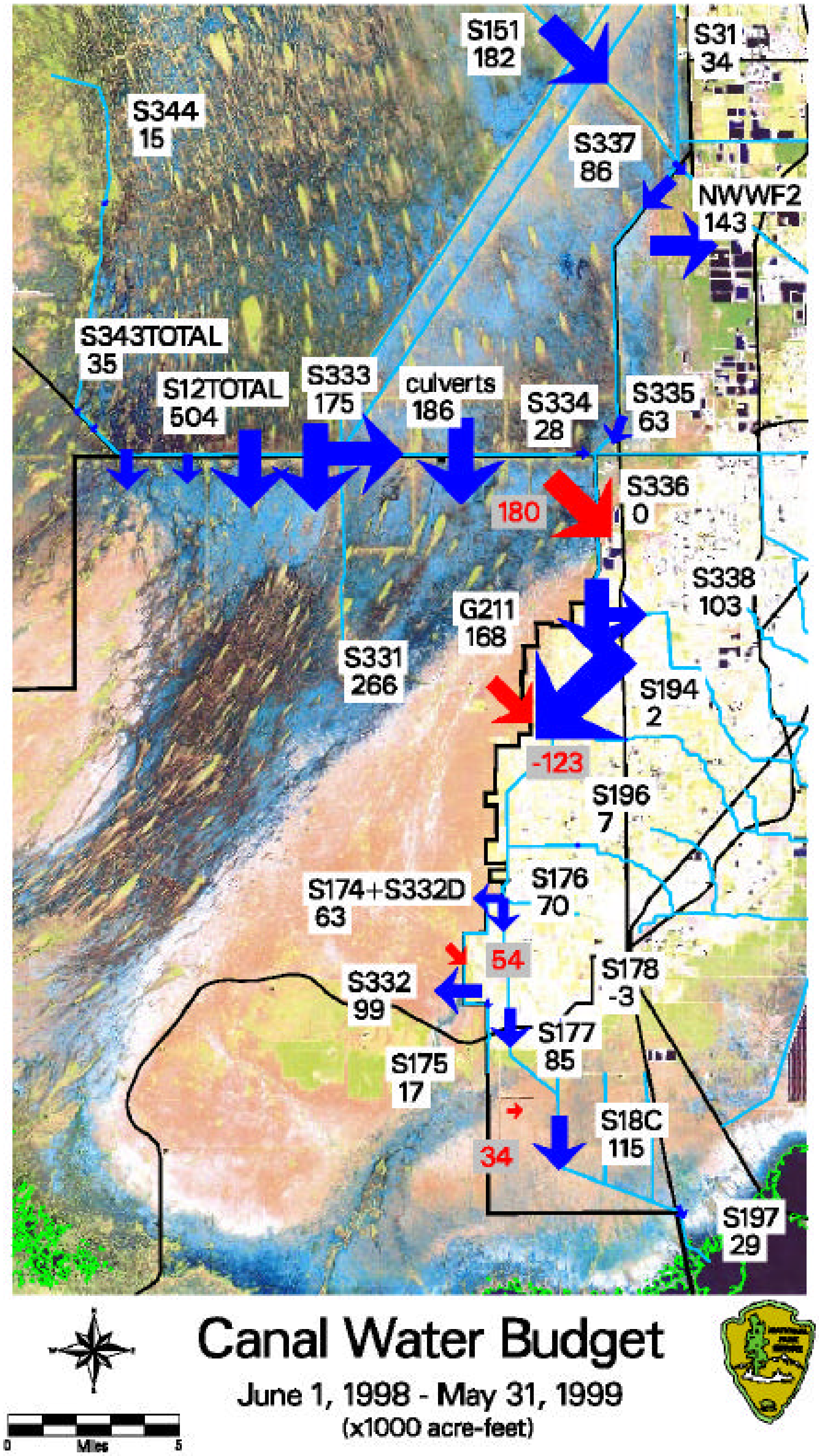

Figure 10. Canal Water Budget June 1, 1998 – May 31, 1999

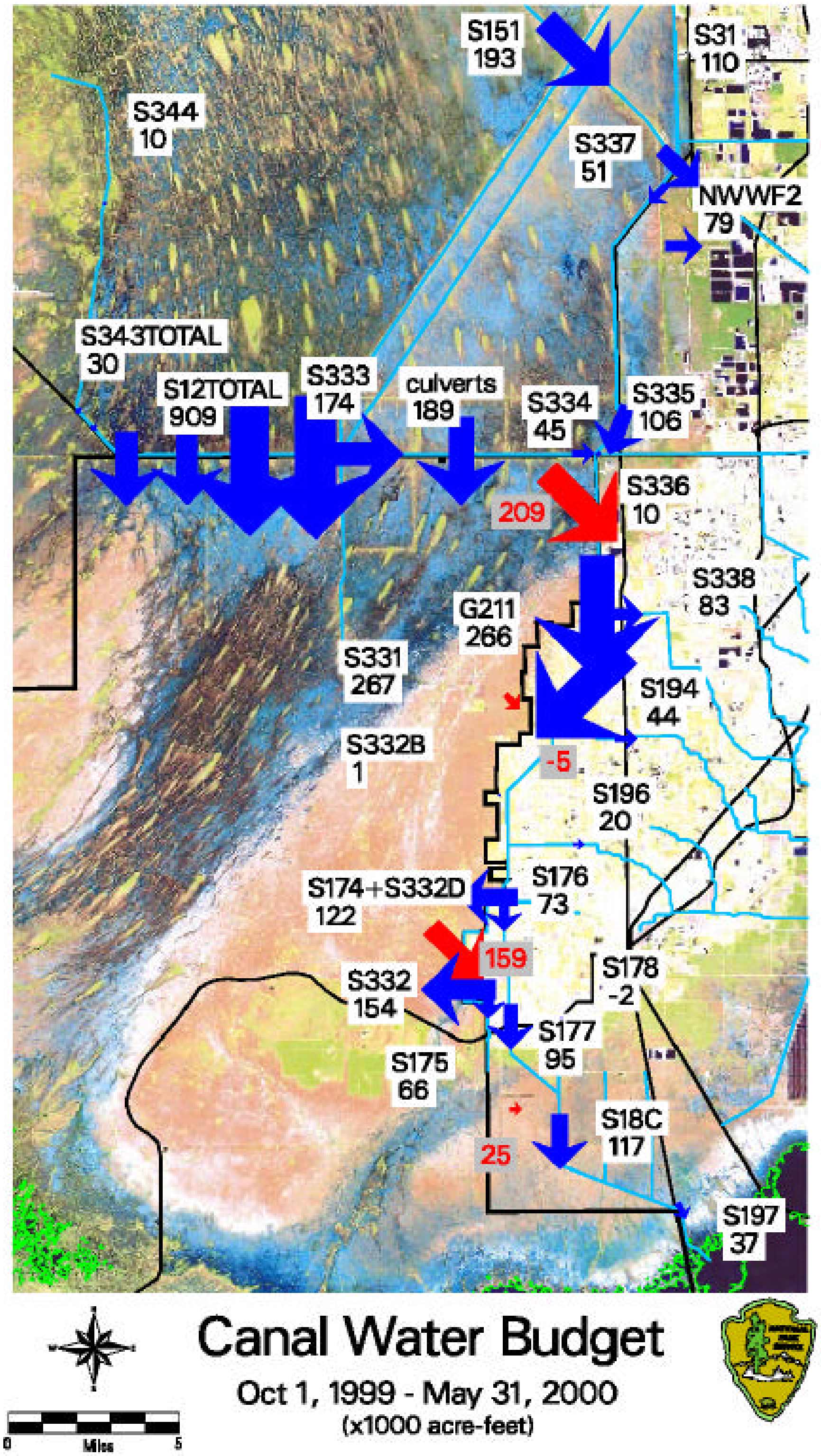

Figure 11. Canal Water Budget June 1, 1999 – May 31, 2000

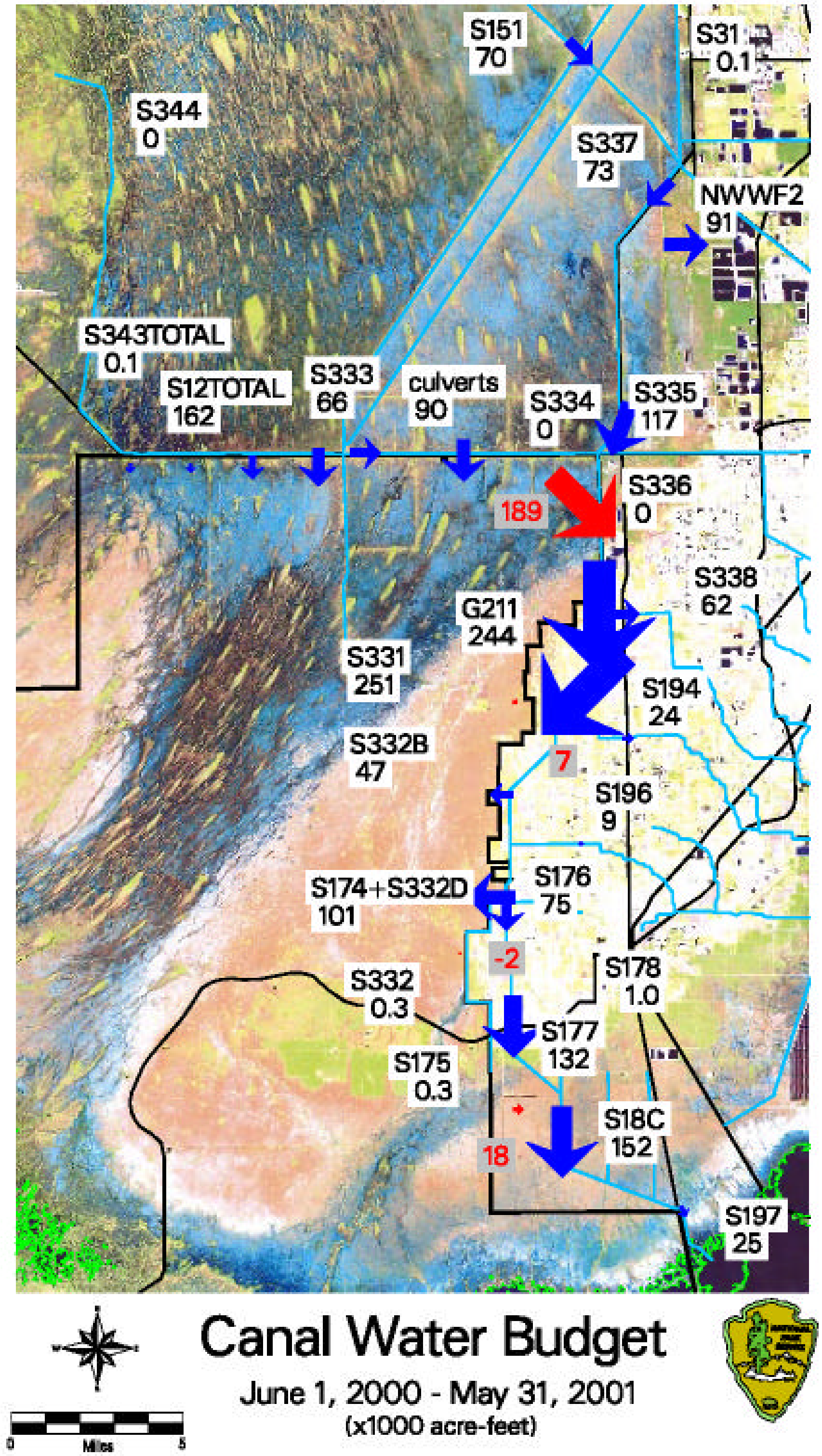

Figure 12. Canal Water Budget June 1, 2000 – May 31, 2001

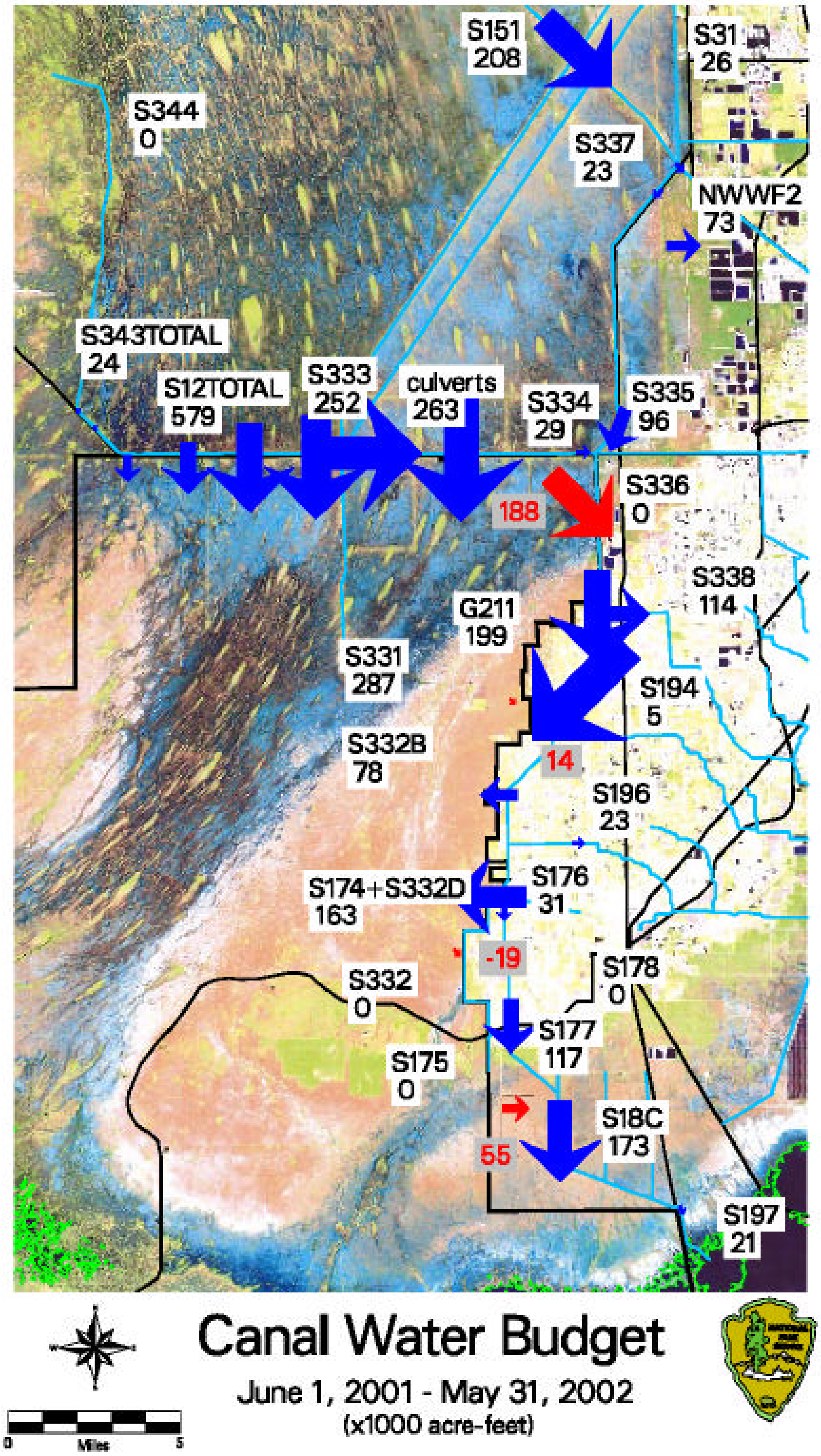

Figure 13. Canal Water Budget June 1, 2001 – May 31, 2002

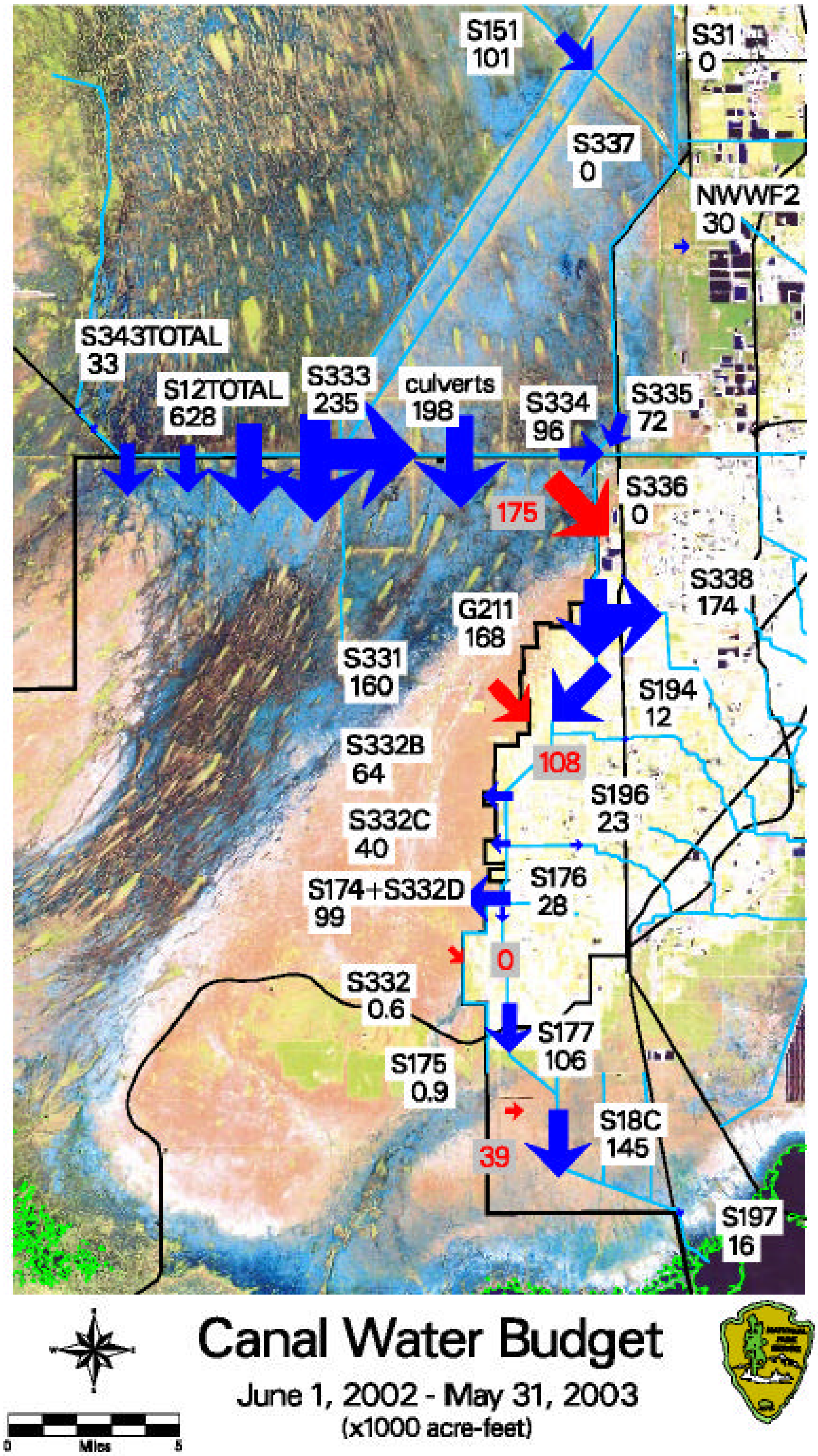

Figure 14. Canal Water Budget June 1, 2002 – May 31, 2003

The pre- and post-ISOP canal water budgets also show a marked difference in the operations around S-332D. S-332 use is minimal in after ISOP implementation, and S-176 flows were also significantly reduced. This change of operations led to close scrutiny of marsh impacts in upper Taylor Slough. Although operations affecting upper Taylor Slough appear to be different after ISOP implementation, the structures in C-111 do not appear significantly different in terms of annual flow volumes. S-177 and S-18C flows don't seem to vary pre- and post-ISOP/IOP. This was not entirely desirable, as the hope was that modification of S-332D operations would result in more flow down lower Taylor Slough. This suggests that C-111 is intercepting a significant amount of S-332D outflow as well as water from Taylor Slough.

The canal and seepage water budget map for the pre-IOP/ISOP wet season of 1997 is shown in Figure 15. Inflows to western Shark Slough and NESS are shown by the total flows S12TOTAL and S333, respectively, and match the quantity shown in Figure F1 in the cumulative flow plot. Typically, there is little wet season inflow into NESS because G-3273 usually precludes S-333 use. The SDCS provides the flood control and water supply operations along the eastern side of ENP. No inflows occurred into L-31N (S-334 and S-335). Flows to the coast (S-338, S-194, and S-196) are shown to total 62 kilo-acre-ft (kAF). Flood protection operations for the 8.5 SMA area conveyed 55 kAF south through S-331.

After Hurricane Irene, the dry season of 2000 showed large discharges into western Shark Slough and NESS. Seepage from NESS into L-31N was conveyed south past G-211 and S-331 (Figure 16). The dry season capacity of the groundwater in the developed areas allowed the S-331 flows to infiltrate into the groundwater and eliminated the massive S-18C and S-197 discharges.

The lack of WCA-3A flows during the wet season of 2000 caused water levels to drop in Dade County, and little flow was recorded in the dry season of 2001 (Figure 17). With the new S-332B pump on line, a small quantity was pumped into the detention area. A change in operational procedures was also implemented to provide reclamation for the Pennsuco and Bird Drive Basin wetlands by opening S-335 for flood control purposes.

By the dry season of 2002 (Figure 18), inflows from both S-334 and S-335 were being passed through G-211 and discharged into S-332B and D, with a slight reduction through S-176. Although S-176 is used less, the operations at S-177 and S-18C were not changed to reflect the increased capacity in the northern part of the SDCS. S-18C discharges appear to have increased slightly with the new lowered operational rules.

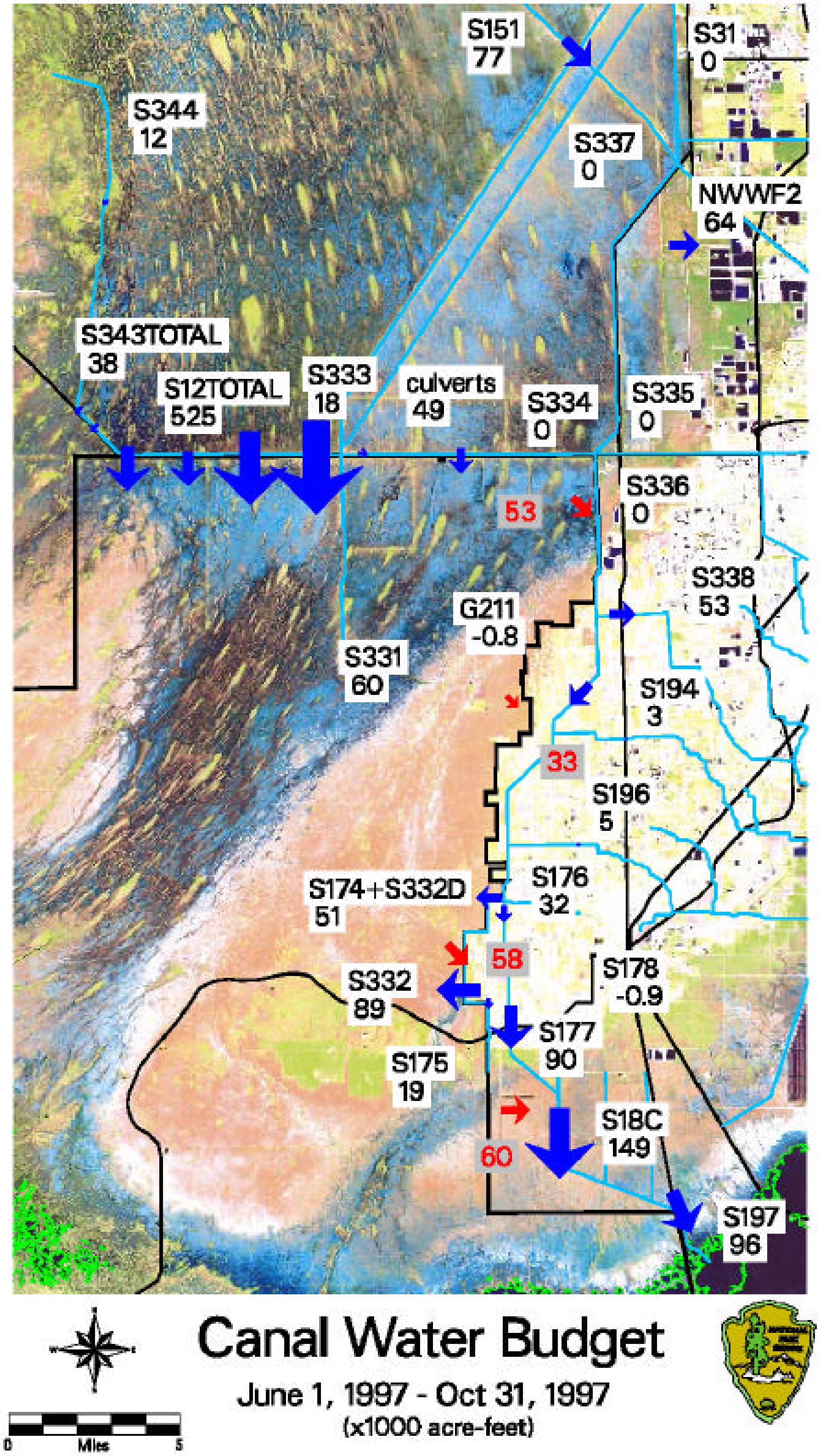

Figure 15. Canal and seepage water budget map for wet season of 1997

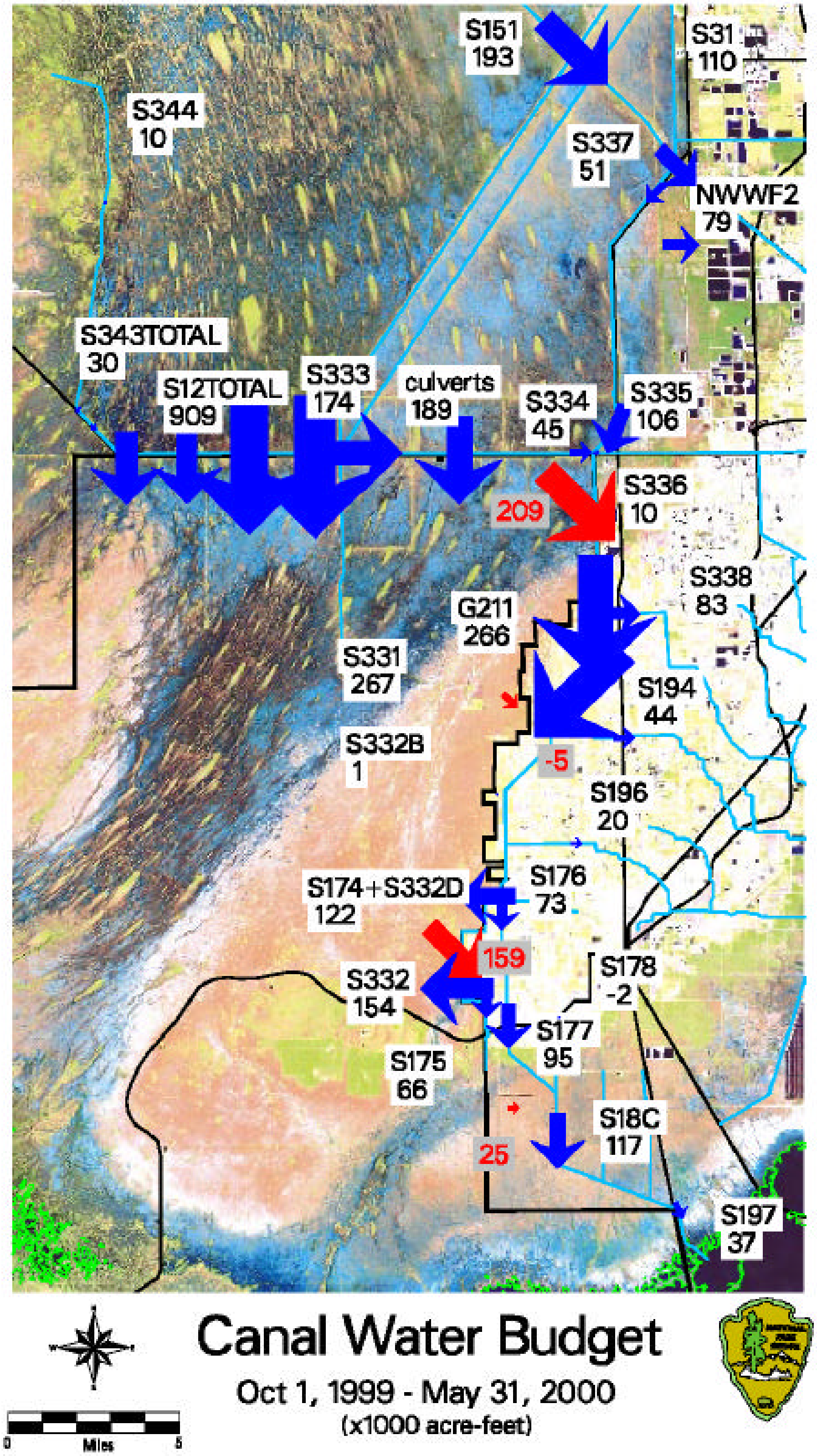

Figure 16. Canal and seepage water budget map for dry season of 2000

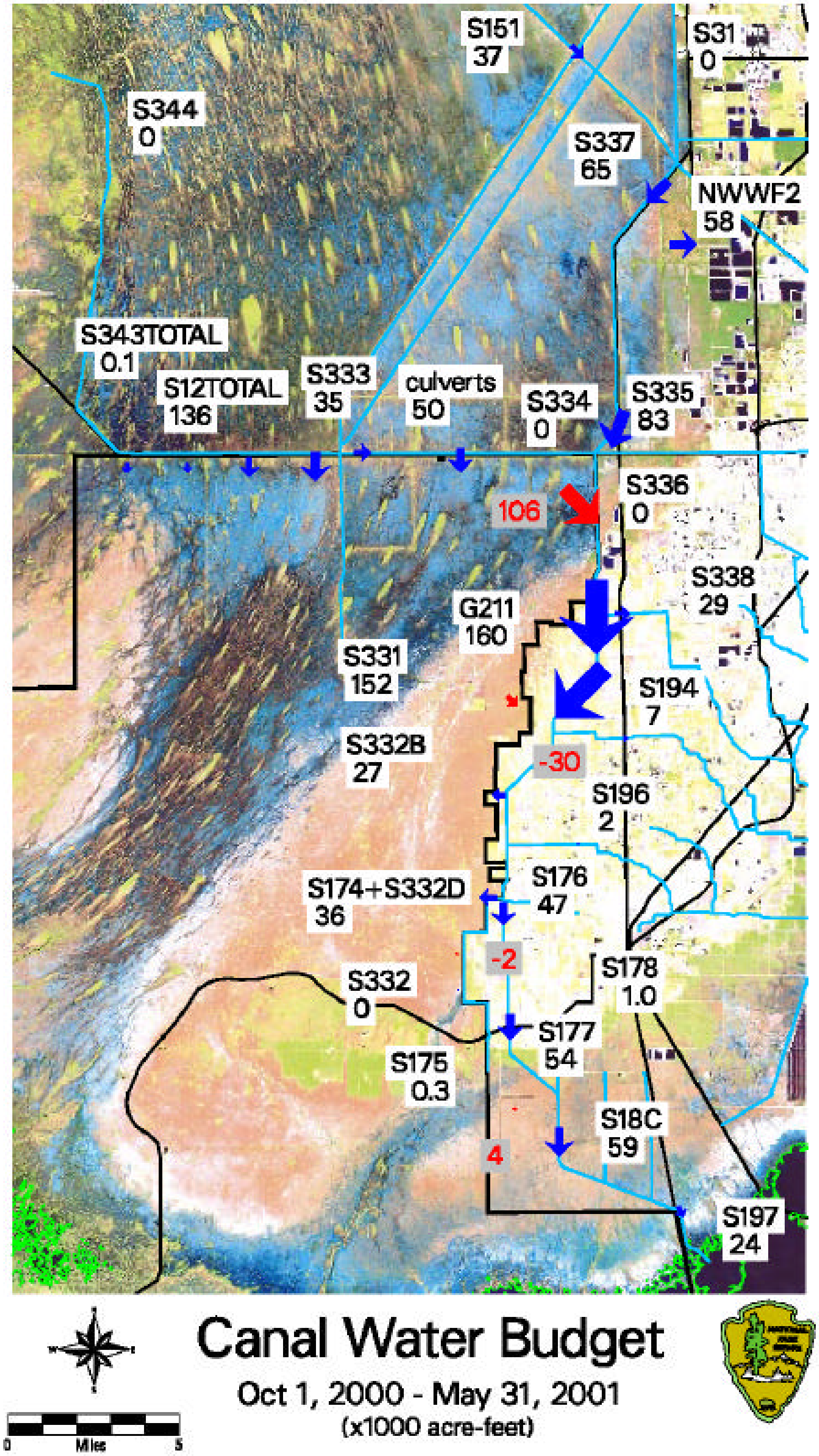

Figure 17. Canal and seepage water budget map for dry season of 2001

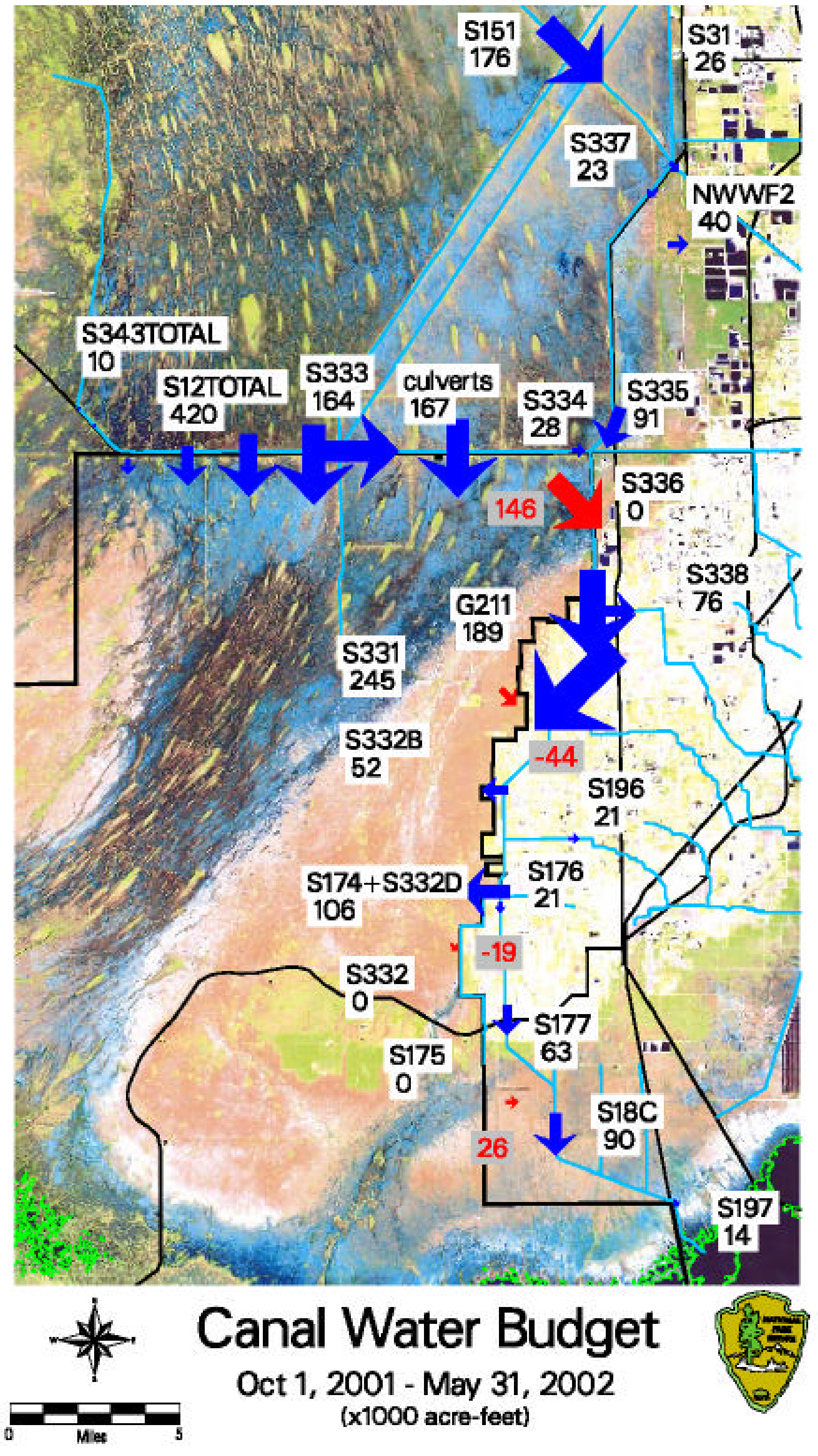

Figure 18. Canal and seepage water budget map for dry season of 2002

3.3 Statistical Analysis

The implementation of the ISOP/IOP involved two fundamental operational changes in addition to several lesser modifications. First, the S-12 structures on the northern boundary of ENP were closed at the end of the wet season in order to reduce flooding of CSSS habitats during the nesting season that extends from March to mid-June. Second, excess water from the water conservation areas was delivered to northeast Shark Slough and to the SDCS and the eastern boundary of ENP through the existing water control structures (S-333, S-334, S-335). Historical hydrologic records during the past three years show a noticeable change in flows through these structures since the implementation of ISOP/IOP. The change is prominent especially during the dry season, and its impact on the hydro-patterns, in turn, affect the biological communities in the Everglades. In April 2003, hydrologists and biologists working within and out of ENP met to discuss the approach to be used in evaluating ISOP/IOP impacts. This group set up the basic definitions and parameters to be analyzed. A consensus was reached that the best way to evaluate the impact of ISOP/IOP is through a statistical model, which uses Before-After and Control-Impact (BACI) comparisons. Therefore, this study applied a simple paired BACI approach to water level data at selected sites in the Everglades. The BACI analysis was used to determine the statistical significance of hydrologic changes that occurred during the ISOP/IOP period. The period of this BACI analysis extends from 1995 to 2002. In the following section, the theory of the BACI approach will be described briefly; along with its application to the hydrologic data, summary of the results of the BACI analysis, and interpretation and discussion.

3.3.1 Methods

Biological communities can be very sensitive to environmental changes and may reflect alterations to the hydrology. Because of the complexity of system models, changes directly related to specific stimuli may be difficult to isolate. Physical modeling is not a viable method of determining biological change. Statistical methods are often used as an alternative; in this case the BACI approach was used to assess the biological effects of operational changes. This method is powerful enough to detect even small changes and thus, has been applied widely to analyze the changes on biological and environmental data (Green, 1993; Steward-Oaten and Bence, 2001; Keough and Mapstone, 1997; Underwood, 1994). The basic form of the BACI approach was popularized by Stewart-Oaten et al. (1986), but given the name BACI only recently. To apply a simple paired BACI analysis, a sampling time is divided into two periods: before and after a system alteration. Also, two spatial locations or sites are used: an impact site and a control site (Figure 19). The impact site is expected to be influenced by the alteration to the system, while the control site is not affected by the change. Given a paired (impact and control) set of data, the BACI approach compares the relative states of two sites between the two periods. The F-value, computed based on an analysis of variance (ANOVA) test, is used to determine whether the change is significant or not (Steward-Oaten and Bence, 2001).

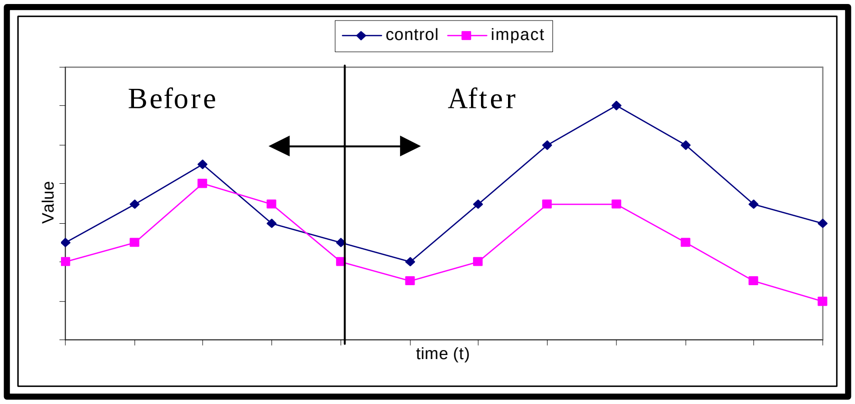

Figure 19. Schematic of a paired time series data set applicable to a simple BACI analysis.

The BACI approach assumes that samples are taken independently and identically over the period of analysis. Data should be normally distributed, or be transformed (logarithm, exponential, or power, etc.) beforehand in order to satisfy the normality condition of data. Here the variable of interest is denoted by $X_{ij}(k)$, where i refers the period (i=Before or After), j is the location (j=Control or Impact), and k is the time of sampling (k=1,…,n=(t_B+t_A)) where n is equal to the total number of paired samples and t_B and t_A are numbers of before and after subsets of the samples. Given the data in Table 8, the linear model that is applied to a paired BACI analysis (Downes et al, 2002; Smith, 2002) is given as:

$$X_{ij}(k) = m + a_i + t(k(i)) + b_j + (ab)_{ij} + e_{ij}(k) \text{......................} Equation(1)$$

where μ is the overall mean, α_i is the effect of period, τ(k(i)) is the time within period, β_j is the effect of site, (αβ) is a single parameter representing the interaction between period and location, and ε is the model error.

Table 8. Data Structure for a paired BACI design

Period	Sampling Occasion	Paired Data Set	
		Control	Impact
Before	1	$X_{BC}(1)$	$X_{BI}(1)$
	:	:	:
	t_B	$X_{BC}(t_B)$	$X_{BI}(t_B)$
After	t_{B+1}	$X_{AC}(t_B+1)$	$X_{AI}(t_B+1)$
	:	:	:
	t_B+t_A (=n)	$X_{AC}(n)$	$X_{AI}(n)$

Table 9. ANOVA table for a paired BACI analysis, where MS stands for the mean squared value estimated by a least squares method (after Smith, 2002).

Source	Sum of Square	Degree of Freedom	F-statistics
Period (Before and After)	MS_{BA}	1	
Error A		t_B+t_A-2	
Time within period	$MS_{t(BA)}$	t_B+t_A-2	
Location (Control and Impact)	MS_{CI}	1	
Interaction (BA x CI)	MS_{BACI}	1	$F=MS_{BACI}/MS_E$
Error B	MS_E	t_B+t_A-2	
Total	MS_{Total}	$2(t_B+t_A)-1$	

Equation 1 differs from a linear regression equation in that it is modeled by parameters without independent variables. The parameters α and β represent the variations between the periods and sites, respectively, while τ is the time-specific component. In other words, the estimated α value indicates the net change of the impact variable between the two periods after filtering out the effect of control variable change. The model parameters (α, β, τ, $\alpha\beta$) were estimated based on a generalized least-squares method, from which the ANOVA statistics were obtained as shown in Table 9.

The F-value (variance) on the above table is an indication of the change in the impact variable. Because the significance level is easier to interpret in the form of an exceedance probability, the F-values, model degrees of freedom and error were used to estimate exceedance probabilities and are presented as such.

3.3.2 Application of BACI Analysis

3.3.2.1 Hydrologic Year

In South Florida, the dry season begins some time between late October and early November and ends in late May or early June of the following year; the wet season extends from this point to October/November. Of course, the precise transition dates vary from year to year, but typically, the hydrologic year is considered to begin on June 1st, the approximate onset of the wet season, and span to May. However, for the purposes of the BACI analysis, the hydrologic year was chosen to begin in the dry season, in other words, span from November to October. This definition of the hydrologic year was selected primarily because it better coincides with the collection and analysis of biological data. Additionally, it allows for the analysis of some hydrologic variables which are defined within the November-October hydrologic year. For example, the maximum dry-down days is the count of consecutive days during which water levels are below the surface. Often this period occurs at the end of the dry season and is interrupted by the first heavy rains of the wet season. Because the wet season may begin any time in late May or early June, by following a hydrologic year that extends across both those months, one is ensured not to miss the transition and to capture the full number of dry-down days. This hydrologic year definition also provides a fair chance to capture the transition into ISOP/IOP. Under the June to May hydrologic year, data from June 1999 to May 2000 cannot be used, as that period is interrupted by the transition from Test 7 to ISOP. Because there are very limited hydrologic and biological data available during the BACI analysis period (1996-2002), salvaging a year's worth of data has a significant impact on the quality of the BACI test. The onset of ISOP occurred in late December of 1999, reasonably close to the November wet-to-dry season transition. Under the November-October hydrologic year, the before period would be Test 7 (June 1995 to October 1999) and the after period would be ISOP/IOP (November 1999 to May 2002). The year annotations used in figures and tables here are defined as shown in Figure 20.

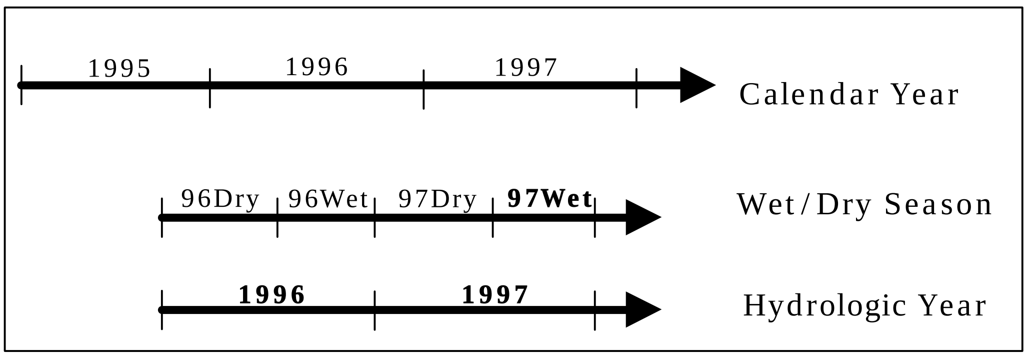

Figure 20. Hydrologic year nomenclature

3.3.2.2 Data and Application

For this study, thirty water level stations, located in ENP and WCA-3A were selected. The following criteria were used to select these stations:

1) Sites have best available records (e.g., minimal missing data) during the BACI analysis period (1995-2002).
2) Sites collectively cover the six sub-basin areas, namely WCA-3A, Western Shark Slough (WSS), NESS, Rocky Glades, Taylor Slough, and the Eastern Panhandle.
3) Sites are located close to biological study areas so that the result of this analysis can be applied directly to the ISOP/IOP biological impact studies.

Of the thirty sampled water level sites, five are monitored by the SFWMD, while the remainder are monitored by ENP. Both agencies' databases (DBHYDRO and

DataForEVER) provided daily data during the BACI analysis period. Minor daily gaps in the retrieved data were filled in based on a linear regression approach. A regression model for a site with missing data was developed using the data at the nearest site (independent variable) that has a similar hydro-pattern to that of missing-data site. The model was then used to estimate daily missing values based on concurrent records at the independent site. If the value at the independent site was also missing, the next-best site was used as an independent variable, and so on, until all gaps were filled in.

Typically, control sites in a hydrologic BACI analysis are gauging stations upstream from the point of alteration. However, for this study, it was nearly impossible to identify unimpacted areas - sites that have not been affected by ISOP/IOP. Instead, this hydrologic BACI analysis used average basin rainfall as a control variable, as recommended by the previous pilot study (Ahn and Mitchell, 2003). Control variables for ENP and WCA-3A sites were average rainfalls for the respective basins (Ahn, 2003; provided by Bill Walker via personal communications). It should be noted that yearly WCA-3A rainfalls are smaller than the corresponding ENP rainfalls. Yearly BACI analyses use yearly rainfalls, while seasonal analyses use the respective seasonal rainfalls. Table 2 (shown previously, in Section 2.1.1) summarizes the rainfall values for each case.

Annual average rainfall during the BACI analysis period is about 3% higher than the long-term average, mainly due to high wet season rainfalls that occurred during the BACI period. Annual ENP rainfalls during the before and after periods are about 63 inches and 55 inches, respectively. Average dry season rainfall during the before period (19 inches) is greater than the long-term average dry season rainfall (17 inches), but rainfall during the after period (13 inches) is less than the long-term average. Average ENP rainfalls of both the long-term and the BACI periods are compared below (Table 10).

Table 10. Average ENP rainfall

Period	Dry Season Rainfall (in)	Wet Season Rainfall (in)	Yearly Rainfall (in)
Long-term (1895-2002)	17.7	38.4	56.1
BACI Period (1996-2002)	16.6	41.4	58.0

3.3.2.3 Hydrologic Variables

The implementation of ISOP/IOP has changed flows at main control structures, such as the S-12s, S-332s, S-175, and S-18C. These stations are located on the northern and eastern boundaries of ENP. The hydrologic BACI analysis was intended to investigate the effects of these ISOP/IOP operations on WCA-3A and ENP. As mentioned previously, the result of the hydrologic BACI analysis will be used by biologists to further define the biological response. Thus, the hydrologic variables were selected based on their relationships, directly or indirectly, to the density and abundance of many biological resources in the Everglades. The hydrologic BACI analysis was designed at seasonal and annual time steps because most biological cycles occur on seasonal or annual intervals and dry-down statistics are defined only at annual time intervals. Based on the above considerations, this study selected the following ten hydrologic variables:

- **Annual, dry, and wet season average water levels** (three variables)
Average water level is an arithmetic yearly or seasonal average of daily water levels.

- **Annual minimum water level**
Minimum water level is the minimum daily value in a year.

- **Annual thirty-day maximum water level**
The maximum thirty-day water level is the maximum of the thirty-day moving-average values over the course of a year. Because maximum water levels are driven by instantaneous rainfall events, this smoothing improves the integrity of such statistics. The thirty-day maximum water level is based on the calendar year because maximums are often recorded during the wet to dry season transition, between October and November.

- **Annual, dry, and wet seasons hydroperiods** (three variables)
Hydroperiod is the number of inundated (ponded) days in a year or a season. Inundation is the condition during which water level is above the land surface elevation at a particular site.

- **Annual maximum consecutive dry-down days**
The maximum consecutive dry-down days is defined as the greatest number of consecutive days during which water levels are below the ground level or some reference level. The dry-down condition in this study was defined as water levels lower than a reference level of two inches below the land surface elevation. This variable is a good indicator for fish abundance. Another important hydrologic indicator for fish biology is the number of days since last dry-down. However, this study excludes this variable in analysis because days of consecutive inundation frequently span multiple years, and the BACI period is too short to distinguish this variable for both before and after periods independently.

- **CSSS nesting season dry days**
The final variable, CSSS nesting season dry days, is defined as the total number of dry days during the CSSS nesting season, which extends from March 1st to June 15th (107 days). Dry, or dry-down, in this case, is defined as periods when water level is below the land surface.

Because different reference levels are used for different analyses, it is interesting to investigate how maximum dry-down days vary with respect to reference level. To obtain a general concept of this variation, data from four arbitrary sites during the hydrologic year 2000 were used. Table 11 shows that the number of consecutive dry-down days decreases at the rate of one or two days per inch of reference level change. This rate seems to be a typical dry-season recession rate in ENP. However, the rate at G-3273 in NESS is larger than that at other sites because the openings and closings of nearby control structures cause water level fluctuations of greater amplitude.

Table 11. Variations of maximum consecutive dry-down days with respect to the change of reference levels, which are calculated based on the daily water level data from November 1999 to October 2000 at four arbitrarily selected stations.

Depth below the Surface Elev.(in)	Maximum Dry-down Days			
	NP-205	G-3273	TSB	R-158
0	41	277	54	337
1	40	208	53	337
2	40	202	52	335
3	39	188	51	334
4	39	178	49	332
5	38	162	49	330
6	37	83	48	313

3.3.2.4 F-Values versus Sample Size

The BACI analysis measures the significance of a change using F-statistics. The computed F-value is compared to a limiting (tabulated) F-value that is a function of significance level and degrees of freedom (d.o.f.) of both the model and the error. If the computed F-value is within the limiting F-value, the change is not significant. Alternatively, if the probability of exceeding the limiting F-value is smaller than a specified significance level (e.g., 5%), the change is not significant at that level. For a paired BACI analysis with n samples from both impact and control sites, the d.o.f. of the model (Equation 1) is n - 2 and the d.o.f. of the error is 2n - 1 (Smith, 2002). Because the hydrologic BACI analysis used in this study was based on a very small sample size (n=7), it was necessary to examine how this small sample size affects the results of a BACI test. Figure 21 shows how the limiting F-value varies with respect to sample size, n. The gradients of limiting F-values do not change much if n is greater than five at either the 5% or 10% significance level. In conclusion, the ANOVA test, with sample size greater than five, gives a fairly reliable evaluation, and thus, is acceptable for the BACI analysis results.

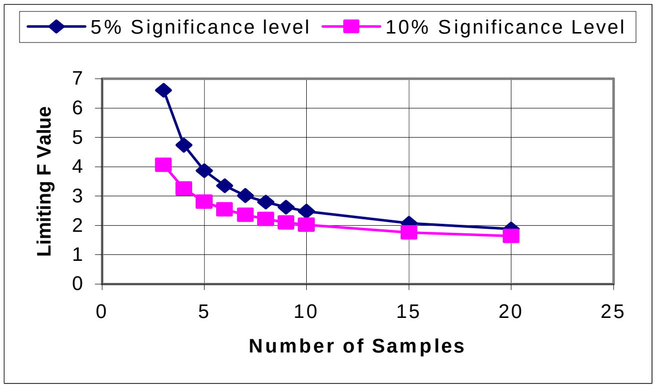

Figure 21. Limiting F-value versus sample size for a paired BACI design.

3.3.2.5 Summary Statistics of Water Level Changes

From daily water level data, summary statistics at both daily and yearly time intervals were computed (Table 12). These statistics are helpful for quantitative evaluation of temporal and spatial water levels changes. They are also useful for the interpretation of the result of the hydrologic BACI analysis. Based on the table, the following observations were made:

- The study area is large but relatively flat with low-elevations that range from 9.3 ft NGVD at the northeast corner of WCA-3A to 0.85 ft NGVD at the Florida Bay area. The flow velocity in the Everglades is extremely low (typically 2~4 cm/s) due to the low relief and dense vegetation cover. Because of these unique topological and hydrologic conditions, the ponding depths and hydroperiods in the region vary from place to place at a small spatial scale. They are also very sensitive to a system change. Because of these small-scale variations, the result of hydrologic BACI analysis presented here should be considered to be site-specific, rather than representative of a large surrounding area.
- Averages of daily water levels at 23 sites during the BACI analysis period are higher than the respective land surface elevations (e.g., surface water sites), but those at 7 sites (namely G-3272, G-3273, NP-206, NTS-1, NTS-14, R-158) are lower (groundwater sites).
- In terms of hydroperiods (for which statistics are not presented here), three sites (3A-4, 3A-28, NP-202) were continuously inundated during the BACI analysis period. Six sites (3A-9, G-618, NP-203, P-36, NE-2, NE-4) were inundated during all the years except 2001. In 2001, water levels dropped remarkably due to below normal rainfalls, especially during the period from June 2000 to May 2001. Total rainfall during that period was fifty inches, which corresponds to a 1-in-4-year drought.
- Water levels at most sites were below the land surface during the dry season- they have a distinct wetting and drying pattern by year. The only exception from this pattern is NP-44, where the water level was below the surface during the seven year BACI period. Also, the R-158 site was dry during the BACI period, except for the year 2002, during which this site was inundated for only seven days.
- Variances of daily water levels are very consistent throughout the area. The standard deviations vary from 0.33 feet at the lower Eastern Panhandle area to 1.25 feet at NTS-14. (Ranges are 2 - 5 ft.) In general, variations of water levels are high through the main path of Shark Slough and low at the edges of the slough, and the lowest in the Eastern Panhandle area.
- Annual average water levels during the before period (Column 7) are higher (about 1/10 of foot) than the respective averages of daily values, except at R-3110 and NTS-1 and R-3110 sites where the situation is opposite. Also, those during the after period (Column 8) are lower (about 2/10 of foot) than the respective average of daily values, except NTS-1 and R-3110. While these two sites reflect an increase in water level which is in accordance with IOP expectations, the general decrease elsewhere is contrary to the Plan’s intent. In general, water levels during the after period are lower than those during the before period mainly

due to rainfall and IOP factors. Table 7 shows that dry season water level changes are generally greater than the wet season changes.

- Average water level differences between the before and the after periods (Table 12, column 9) are high (0.2-0.5 ft) in WCA-3A and Shark Slough, low (~0.1 ft) in Rocky Glades and Taylor Slough, and very low (-0.05 ft) in Panhandle. The changes at five sites in NESS are nearly identical (-0.25 ft). In general, inter-annual ranges of daily water levels are much higher than within year ranges, indicating that the fluctuations of water levels in the area are non-stationary over years.

Table 12. Summary statistics of water levels (ft NGVD) during the hydrologic BACI analysis period (1996-2002).

Sub Basin	Site	Surface Eleva-tion	Average of Daily Values	S.D of Daily Values	Range Of Daily Values	Average of Yearly Means		Change of Means (After-Before)
						Before	After	
WCA-3	**3A-9**	9.30	10.93	0.80	4.99	10.98	10.71	-0.26
	3A-3	8.60	10.43	1.02	5.42	10.56	10.12	-0.45
	3A-4	8.26	10.34	0.85	4.50	10.42	10.08	-0.34
	3A-28	7.06	9.79	0.79	4.17	9.85	9.55	-0.30
	3B-SE	5.71	7.05	0.92	5.85	7.22	6.67	-0.55
WSS	**NP-201**	6.17	7.82	0.95	5.53	8.03	7.37	-0.66
	NP-202	5.33	7.17	0.72	3.78	7.28	6.89	-0.40
	NP-203	4.42	6.42	0.69	3.85	6.56	6.16	-0.40
	NP-205	5.86	6.48	0.92	5.77	6.64	6.11	-0.53
	OT	0.89	2.34	0.68	3.90	2.45	2.10	-0.35
	P-34	1.86	2.98	0.80	4.77	3.09	2.72	-0.37
	P-36	3.26	4.42	0.52	3.35	4.50	4.23	-0.27
	NP-62	2.50	2.95	0.78	5.72	2.97	2.73	-0.24
	P-38	0.85	1.76	0.53	3.26	1.80	1.63	-0.16
	NP-46	1.31	1.57	0.56	4.15	1.60	1.47	-0.13
NESS	**G-618**	6.35	7.15	0.46	4.24	7.24	6.96	-0.28
	NE-2	5.62	6.92	0.52	4.08	7.00	6.73	-0.27
	NE-4	5.50	6.84	0.52	3.83	6.90	6.67	-0.23
	G-3272	6.83	6.50	0.79	5.00	6.54	6.31	-0.23
	G-3273	7.06	6.44	0.78	5.15	6.49	6.24	-0.25
Rocky Glades	**NP-206**	5.99	5.82	0.88	5.01	5.87	5.64	-0.23
	R-3110	5.10	4.59	1.06	4.95	4.57	4.61	0.05
	NP-44	5.02	3.64	1.12	5.80	3.66	3.56	-0.11
Taylor Slough	**NTS-1**	5.04	4.31	0.94	4.57	4.25	4.44	0.19
	NTS-14	3.98	3.92	1.25	5.81	3.94	3.87	-0.07
	TSB	3.51	3.62	1.03	5.18	3.68	3.53	-0.15
	P-37	0.90	1.55	0.50	3.49	1.62	1.43	-0.19
Eastern Pan-Handle	**R-158**	4.55	2.90	0.78	4.78	2.90	2.87	-0.03
	EVER7	1.95	2.21	0.42	2.64	2.22	2.16	-0.06
	EPSW	1.01	1.51	0.33	2.43	1.52	1.48	-0.04

3.4 Result of BACI Analysis

This study applied a paired BACI analysis to test the significance of the ISOP/IOP impact on hydrology. The BACI approach was applied to ten stage-related hydrologic variables at thirty selected sites located in WCA-3A and ENP. Each variable at each site was analyzed independently, making a total of 300 BACI runs. Both stage and rainfall data were log-transformed in order to ensure a normality condition. This log-transformation was also important because water level (ft NGVD) and annual rainfall (inches) are different orders of magnitudes – the control variable is generally one order of magnitude higher than that of impact variable. During the calibration of a BACI model (Equation 1), the parameters that relate to both impact and control variables are fit simultaneously with a least-squares method, so that under the conditions of this analysis, the lower-magnitude impact variables are given less weight compared to the control variables. This could result in inaccurate parameters for the impact-related parameter, but is a problem that was alleviated through the log-transformation of the data.

This study used the probability exceeding an estimated F-value as an indicator of change. The limiting probability was determined based on a significance level and degrees of freedom of both model and error. Typically, a 5% or 10% significance level is used in BACI analyses (Stewart-Oaten et al., 1986). Instead, this study adopted the following four levels of change: less than 5% as very significant; 5-10% as significant; 10-15% as moderately (probable) significant; and greater than 15% as no-impact. The reason to use a 10-15% significance level is that, in many cases, probability values are slightly over 10% level (e.g., 10.9%, 11.1%). These cases are not classified as no-impact in a conservative manner. Table 13 summarizes the result of BACI analysis. It should be noted that the significance of impact, based on a BACI analysis, is a relative term. That is, some sites have large changes in terms of magnitude, but they are labeled as no-impact when the variability of data within site is relatively large compared to the variability between before and after periods. Hydroperiods and dry-down days at a couple of sites are constant over the before and after periods, especially when water levels are always above or below the respective land surface elevation. In such cases, the BACI approach is not applicable, thus the probability values of these sites are arbitrarily set to 99.9% (no-impact).

In addition to the BACI significance test, it is interesting to note the magnitude of change experienced under ISOP/IOP. This change was estimated based on a generalized least-squares fitting of Equation 1. It should be noted that the estimated change under ISOP/IOP is only an approximation based on yearly average values. More accurate estimation is potentially possible with the use of a sophisticated model at smaller time intervals such as daily or weekly steps.

Table 13. Probability (%) exceeding the limiting F value obtained from the hydrologic BACI analysis, where the impact is classified into following four categories:

Color	Prob.>F	Impact
(magenta)	<5 %	Very Significant
(yellow)	5~10 %	Significant
(green)	10~15 %	Moderate
White	>15 %	No-impacts

Sub Basin	Site	Average Water levels (ft NGVD) Year	Average Water levels (ft NGVD) Dry	Average Water levels (ft NGVD) Wet	1-d Min in ft NGVD	30-D Max in ft NGVD	Hydroperiods Year	Hydroperiods Dry	Hydroperiods Wet	Max Dry-down Days	CSSS Nesting Season Dry Days
WCA-3	3A-9	20.7	1.4	82.0	3.8	10.8	22.6	2.2	75.0	21.1	28.7
	3A-3	27.3	1.6	94.5	4.4	17.2	24.1	2.7	71.0	7.0	5.2
	3A-4	23.4	1.4	86.2	3.3	11.3	99.9	99.9	99.9	99.9	99.9
	3A-28	23.6	1.5	82.2	4.6	7.7	99.9	99.9	99.9	99.9	99.9
	3B-SE	41.4	1.6	93.8	14.3	5.0	68.0	91.4	73.3	6.8	5.7
SWSS	NP-201	93.7	16.5	48.8	62.9	82.0	76.6	61.9	84.1	2.6	1.6
	NP-202	73.2	10.2	52.9	10.9	58.0	42.9	8.2	99.9	99.9	20.5
	NP-203	77.6	11.1	53.4	21.1	54.0	45.7	8.5	99.9	19.1	21.8
	NP-205	90.8	20.6	67.3	90.7	65.9	47.3	55.3	86.7	19.6	11.0
	OT	86.2	33.8	50.5	82.1	94.7	72.4	17.3	85.3	99.9	4.8
	P-34	92.0	26.6	48.9	62.9	85.6	77.8	65.6	90.3	13.1	9.0
	P-36	75.3	9.7	55.7	20.3	45.7	93.3	13.0	55.0	23.3	15.3
	NP-62	87.2	13.1	60.4	89.3	39.6	78.6	72.4	68.1	10.9	18.4
	P-38	86.9	12.1	56.1	74.0	27.9	88.5	38.1	74.5	2.2	8.1
	NP-46	81.0	16.6	79.2	40.8	46.3	96.6	37.3	77.9	36.0	11.8
NESS	G-618	63.8	9.8	69.6	26.9	39.0	65.4	64.2	52.0	17.3	6.6
	NE-2	66.1	9.3	68.1	21.3	35.8	83.8	44.8	64.1	24.7	24.9
	NE-4	61.9	8.8	70.9	15.0	37.6	83.4	17.9	77.6	24.3	24.3
	G-3272	64.8	8.0	69.8	23.9	33.0	53.3	83.9	72.8	69.6	24.4
	G-3273	67.0	9.1	73.7	26.6	34.2	63.4	58.1	90.8	4.7	31.7
Rocky Glades	NP-206	66.9	9.2	77.7	36.1	43.3	62.7	85.3	61.4	29.2	23.8
	R-3110	45.0	4.3	98.3	32.0	23.7	60.3	34.0	89.7	88.4	2.6
	NP-44	61.8	7.8	94.6	76.8	34.3	95.0	99.9	86.0	99.8	28.4
Taylor Slough	NTS-1	33.8	4.0	81.4	38.5	14.3	4.4	6.6	8.2	69.8	25.7
	NTS-14	59.2	7.1	86.5	70.4	27.2	93.8	66.9	56.8	59.2	5.3
	TSB	71.9	11.2	73.2	68.9	33.5	64.0	95.8	31.4	24.7	20.9
	P-37	92.8	13.0	55.5	57.9	56.1	88.5	29.9	60.8	12.2	14.3
Eastern Pan-handle	R-158	51.7	6.6	70.8	55.1	15.2	84.0	10.9	28.9	13.9	31.7
	EVER7	55.4	6.5	72.4	6.4	37.3	96.0	20.8	48.8	45.6	47.6
	EPSW	52.2	5.0	73.1	11.1	42.3	88.9	16.0	64.6	62.6	50.6

Tables 14 through 17 summarize the ISOP/IOP change. The “change” referred to in the tables is defined as the average “after” condition minus the average “before” condition. The total change was not isolated from the effect of rainfall and was computed from historical data. Figures 26 through 31 show the ISOP/IOP impact maps organized by hydrologic variable. The four minimally impacted variables were excluded. The results shown in these tables and figures are discussed following.

3.4.1.1 Yearly and Wet Season Water Levels

The results of BACI analysis revealed no ISOP/IOP impact on annual or wet season water levels at any site. The probabilities exceeding the limiting F-value for both annual and wet season water levels are equally high. Changes in average water levels were large in WCA-3A and the northern part of WSS compared to those in the southern sub-basins. The average annual stage change in the Eastern Panhandle was very small (less than 1/10 of a foot). Water levels at all sites show a decreasing trend in time. This trend is likely due to below normal rainfalls during the after period in addition to the effects of ISOP/IOP operations. The ISOP/IOP changes for both annual and wet season water levels are not shown (on Table 22) because the impacts are not significant.

3.4.1.2 Dry Season Water Levels

The ISOP/IOP impact on dry season water levels was the most significant among the ten selected hydrologic variables. Only five out of thirty sites (NP-201, NP-205, OT, P-34, and NP-46) were found to be unimpacted by ISOP/IOP. Spatially, the impact is more significant in WCA-3A than in ENP. The changes in dry season water levels in the Rocky Glades, Taylor Slough, and the Eastern Panhandle are statistically significant (5-15% significance level). The main channel of Shark Slough is also potentially impacted, while the boundaries of Shark Slough are not impacted at all. The magnitudes of water level changes during the dry season are nearly equal to the respective annual changes. Table 14 shows that the ISOP/IOP changes in most cases are positive (increased during the ISOP/IOP period), except in the WCA-3A area. The ISOP/IOP changes in WCA-3A are due to both ISOP/IOP operation changes and other management factors on the upper basins including Lake Okeechobee, Everglades Agricultural Area, and Water Conservation Areas.

3.4.1.3 Minimum and Maximum Water Levels

The ISOP/IOP likely affected minimum and maximum water levels, as changes in these variables were very significant in WCA-3, however, the impacts are minimal in ENP. (See Table 15.) In WCA-3, all sites experienced a lowering of both minimum and maximum water levels, showing overall drier conditions after the implementation of ISOP. For minimum water levels in ENP, only one site (EVER-7) has a probability less than 10% and another three sites (NP-202, NE-4, EPSW) are potentially impacted. For thirty-day maximum water levels, all ENP sites except NTS-1 were found to experience no significant impact.

Table 14. Changes (After –Before) of average annual water levels (ft NGVD) during the BACI period (1996-2002), where "positive" change indicates an increasing trend in time, total change is by both IOP and rainfall factors, and probability values are from Table 6.

Sub Basin	Site	Yearly		Dry Season			Wet Season	
		Prob.> F	Total Change	Prob.> F	Total Change	Change By IOP	Prob.> F	Total Change
WCA-3	3A-9	20.7	-0.26	1.4	-0.23	-0.01	82.0	-0.32
	3A-3	27.3	-0.45	1.6	-0.40	-0.02	94.5	-0.52
	3A-4	23.4	-0.34	1.4	-0.32	-0.01	86.2	-0.36
	3A-28	23.6	-0.30	1.5	-0.32	-0.01	82.2	-0.28
	3B-SE	41.4	-0.55	1.6	-0.58	-0.06	93.8	-0.50
SWSS	NP-201	93.7	-0.66	16.5	-0.75	0.01	48.8	-0.54
	NP-202	73.2	-0.40	10.2	-0.36	0.05	52.9	-0.45
	NP-203	77.6	-0.40	11.1	-0.38	0.04	53.4	-0.43
	NP-205	90.8	-0.53	20.6	-0.78	0.01	67.3	-0.20
	OT	86.2	-0.35	33.8	-0.47	-0.05	50.5	-0.18
	P-34	92.0	-0.37	26.6	-0.48	-0.05	48.9	-0.22
	P-36	75.3	-0.27	9.7	-0.26	0.06	55.7	-0.29
	NP-62	87.2	-0.24	13.1	-0.29	0.09	60.4	-0.17
	P-38	86.9	-0.16	12.1	-0.17	0.07	56.1	-0.15
	NP-46	81.0	-0.13	16.6	-0.21	0.07	79.2	-0.02
NESS	G-618	63.8	-0.28	9.8	-0.33	0.06	69.6	-0.21
	NE-2	66.1	-0.27	9.3	-0.29	0.07	68.1	-0.24
	NE-4	61.9	-0.23	8.8	-0.25	0.07	70.9	-0.19
	G-3272	64.8	-0.23	8.0	-0.26	0.07	69.8	-0.20
	G-3273	67.0	-0.25	9.1	-0.32	0.07	73.7	-0.14
Rocky Glades	NP-206	66.9	-0.23	9.2	-0.34	0.08	77.7	-0.08
	R-3110	45.0	0.05	4.3	-0.01	0.16	98.3	0.13
	NP-44	61.8	-0.11	7.8	-0.24	0.14	94.6	0.08
Taylor Slough	NTS-1	33.8	0.19	4.0	0.10	0.15	81.4	0.31
	NTS-14	59.2	-0.07	7.1	-0.13	0.15	86.5	0.02
	TSB	71.9	-0.15	11.2	-0.18	0.09	73.2	-0.10
	P-37	92.8	-0.19	13.0	-0.21	0.05	55.5	-0.15
Eastern Pan-Handle	R-158	51.7	-0.03	6.6	0.01	0.12	70.8	-0.08
	EVER7	55.4	-0.06	6.5	-0.05	0.09	72.4	-0.07
	EPSW	52.2	-0.04	5.0	-0.03	0.11	73.1	-0.05

Table 15. Changes (After –Before) of annual minimum and maximum water levels (ft NGVD) during the BACI period (1996-2002), where "positive" change indicates an increasing trend in time, total change is by both IOP and rainfall factors, and probability values are from Table 6.

Sub Basin	Site	1-D Minimum			Maximum of 30-D Moving averages		
		Prob.>F	Total Change	Change By IOP	Prob.>F	Total Change	Change by IOP
WCA-3	3A-9	3.8	-0.62	-0.01	10.8	-0.52	-0.17
	3A-3	4.4	-0.69	-0.05	17.2	-0.72	-0.18
	3A-4	3.3	-0.50	-0.04	11.3	-0.51	-0.17
	3A-28	4.6	-0.53	-0.03	7.7	-0.41	-0.17
	3B-SE	14.3	-1.05	-0.15	5.0	-0.33	-0.19
SWSS	NP-201	62.9	-1.78	-0.17	82.0	-0.68	-0.17
	NP-202	10.9	-0.51	0.04	58.0	-0.41	-0.15
	NP-203	21.1	-0.80	-0.02	54.0	-0.32	-0.14
	NP-205	90.7	-1.55	-0.15	65.9	-0.44	-0.14
	OT	82.1	-0.74	-0.33	94.7	-0.33	-0.20
	P-34	62.9	-0.97	-0.44	85.6	-0.47	-0.21
	P-36	20.3	-0.46	0.01	45.7	-0.17	-0.14
	NP-62	89.3	-0.70	0.04	39.6	-0.08	-0.14
	P-38	74.0	-0.59	-0.21	27.9	0.00	-0.13
	NP-46	40.8	-0.56	-0.66	46.3	-0.05	-0.12
NESS	G-618	26.9	-0.91	0.00	39.0	-0.17	-0.13
	NE-2	21.3	-0.76	0.01	35.8	-0.07	-0.12
	NE-4	15.0	-0.57	0.03	37.6	-0.09	-0.12
	G-3272	23.9	-0.75	-0.05	33.0	-0.03	-0.12
	G-3273	26.6	-0.77	-0.04	34.2	-0.04	-0.12
Rocky Glades	NP-206	36.1	-0.71	-0.05	43.3	-0.13	-0.12
	R-3110	32.0	-0.50	-0.02	23.7	0.15	-0.08
	NP-44	76.8	-0.48	0.05	34.3	0.03	-0.08
Taylor Slough	NTS-1	38.5	-0.62	-0.08	14.3	0.36	-0.05
	NTS-14	70.4	-0.57	-0.05	27.2	0.12	-0.08
	TSB	68.9	-0.60	-0.13	33.5	-0.01	-0.11
	P-37	57.9	-0.58	-0.30	56.1	-0.12	-0.14
Eastern Pan-Handle	R-158	55.1	-0.51	-0.13	15.2	-0.04	-0.15
	EVER7	6.4	-0.17	0.08	37.3	-0.05	-0.12
	EPSW	11.1	-0.17	0.07	42.3	-0.06	-0.12

3.4.1.4 Yearly and Wet Season hydroperiods

The ISOP/IOP impacts on annual and wet season hydroperiods are quite similar to those of water levels, with the exception of wet season hydroperiods at NTS-1. The yearly and wet season hydroperiods at NTS-1 during the ISOP/IOP period increased 93 days and 38 days, respectively. These changes were due to the operation of S-332B pump. Both the 3A-3 and 3A-4 sites in WCA-3A were always inundated during the BACI analysis period (1995-2002). Annual hydroperiods at most sites have a decreasing trend during the ISOP/IOP period. This decreasing trend corresponds mainly to the decreasing dry season hydroperiods. Exceptions are at G-3273, R-3110 and NTS-1, where hydroperiods were increased during the ISOP/IOP period. Magnitudes of the changes in hydroperiods during the wet season are much less than those during the dry season (Table 16). The ISOP/IOP changes for both annual and wet season hydroperiods are nearly zero (on Table 16), indicating no impact.

3.4.1.5 Dry Season Hydroperiods

Dry season hydroperiods at seven sites, fewer than the number for dry season water levels, changed significantly after the ISOP/IOP implementation. Because hydroperiods are primarily affected by major storm events during the wet season, hydroperiods behave differently from water levels. Dry season hydroperiods at seven out of the thirty sites (3A-9, 3A-3, NP-202, NP-203, P-36, NTS-1, R-158) show significant change at the 5-15% level. For these seven sites, dry season water levels also show significant change after ISOP/IOP. The NP-44 site is always dry, considered no impact. The hydroperiods at four sites (G-3273, R-3110, NTS-1, R-158) increased noticeably during the after period. Unlike the water level variables, changes in the dry season hydroperiods are moderate at the sites with significantly changed hydroperiods (Table 16).

3.4.1.6 Maximum Consecutive Drydown Days

Maximum consecutive dry-down days at five sites were significantly different after ISOP/IOP . The impacts at NP-201, P-38, and G-3273 are very significant. Also, dry-down days at these three sites increased noticeably (27, 20, 69 days, respectively) during the ISOP/IOP period. Dry-down days at four sites (3A-4, 3A-28, NP-202, OT) were not changed at all - no impact. Maximum dry-down days at most sites are increased during the ISOP/IOP period, except four sites (G-3272, R-3110, NP-44, NTS-1) that decreased moderately.

Table 16. Changes (After –Before) of hydroperiods (days) during the BACI period (1996-2002), where "positive" change indicates an increasing trend in time, total change is by both IOP and rainfall factors, and probability values are from Table 6.

Sub Basin	Site	Yearly			Dry Season			Wet Season		
		Prob. >F	Total Change	Change by IOP	Prob.> F	Total Change	Change By IOP	Prob.> F	Total Change	Change by IOP
WCA-3	3A-9	22.6	-9	0	2.2	-7	-1	75.0	-2	0
	3A-3	24.1	-11	0	2.7	-10	-2	71.0	-1	0
	3A-4	99.9	0	0	99.9	0	0	99.9	0	0
	3A-28	99.9	0	0	99.9	0	0	99.9	0	0
	3B-SE	68.0	-68	0	91.4	-53	0	73.3	-16	0
SWSS	NP-201	76.6	-42	0	61.9	-41	0	84.1	-1	0
	NP-202	42.9	-2	0	8.2	-2	0	99.9	0	0
	NP-203	45.7	-3	0	8.5	-3	0	99.9	0	0
	NP-205	47.3	-62	0	55.3	-68	0	86.7	6	0
	OT	72.4	-17	0	17.3	-17	0	85.3	0	0
	P-34	77.8	-41	0	65.6	-42	0	90.3	1	0
	P-36	93.3	-24	0	13.0	-12	-2	55.0	-12	0
	NP-62	78.6	-35	0	72.4	-28	0	68.1	-7	0
	P-38	88.5	-35	0	38.1	-32	0	74.5	-4	0
	NP-46	96.6	-22	0	37.3	-20	0	77.9	-3	0
NESS	G-618	65.4	-53	0	64.2	-39	0	52.0	-14	0
	NE-2	83.8	-37	0	44.8	-30	0	64.1	-8	0
	NE-4	83.4	-20	0	17.9	-17	0	77.6	-3	0
	G-3272	53.3	-30	0	83.9	-19	0	72.8	-10	0
	G-3273	63.4	3	0	58.1	7	1	90.8	-4	0
Rocky Glades	NP-206	62.7	-37	0	85.3	-25	0	61.4	-12	0
	R-3110	60.3	14	0	34.0	15	1	89.7	-1	0
	NP-44	95.0	-1	-1	99.9	0	0	86.0	-1	-1
Taylor Slough	NTS-1	4.4	93	1	6.6	54	7	8.2	38	0
	NTS-14	93.8	-9	0	66.9	-1	0	56.8	-8	0
	TSB	64.0	-41	0	95.8	-23	0	31.4	-18	0
	P-37	88.5	-34	0	29.9	-25	0	60.8	-9	0
Pan Handle	R-158	84.0	-1	0	10.9	2	3	28.9	-3	-1
	EVER7	96.0	-24	0	20.8	-11	0	48.8	-14	0
	EPSW	88.9	-19	0	16.0	-12	0	64.6	-7	0

3.4.1.7 CSSS Nesting Season Dry-down Days

All thirty sites were analyzed, but only ten sites are located within the CSSS sub-population zones. This variable is the second-most sensitive to IOP. In all, twelve out of thirty sites were impacted by IOP, but probability values exceeding F are relatively low (the average of 28 sites, excluding 3A-3 and 3A-28, is about 19%), indicating that most sites are more or less impacted by IOP. Nesting season dry-down days at all but two sites (3A-4, 3A-28) are increased during the IOP period. An average increase of nesting season dry-down days at these 28 sites is nineteen days. Figure 22 plots the changes of dry-down days at ten sites that are located within the CSSS sub-population habitat areas (A through E). An average increase of dry-down days during the after period at these ten sites is 22 days.

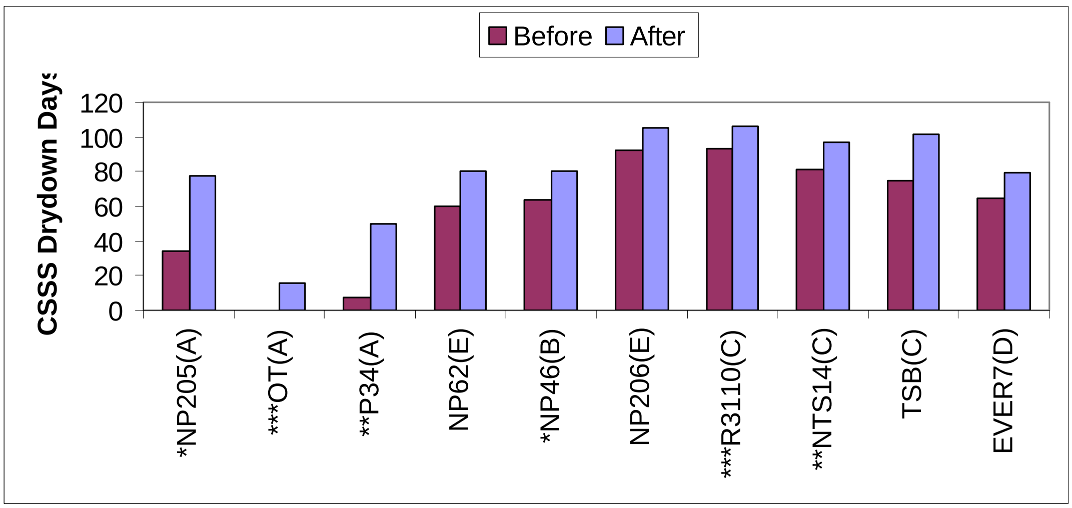

Figure 22. Changes of average CSSS nesting period dry-down days, where * indicates the degree of impact (*: very significant, **: significant, *: moderate), and the character after site name is the CSSS sub-population habitat Zone (A-E).**

Table 17. Changes (After –Before) of drydown days during the BACI period (1996-2002), where "positive" change indicates an increasing trend in time, total change is by both IOP and rainfall factors, and probability values are from Table 6.

Sub Basin	Site	Maximum Drydown Days			CSSS Nesting Drydown Days		
		Prob.>F	Total Change	Change by IOP	Prob.>F	Total Change	Change by IOP
WCA-3	3A-9	21.1	5	0	28.7	7	0
	3A-3	7.0	4	2	5.2	11	7
	3A-4	99.9	0	0	99.9	0	0
	3A-28	99.9	0	0	99.9	0	0
	3B-SE	6.8	61	14	5.7	46	19
SWSS	NP-201	2.6	27	14	1.6	41	21
	NP-202	99.9	0	0	20.5	2	0
	NP-203	19.1	1	0	21.8	3	0
	NP-205	19.6	33	1	11.0	44	1
	OT	99.9	7	6	4.8	16	12
	P-34	13.1	26	5	9.0	43	3
	P-36	23.3	7	1	15.3	16	2
	NP-62	10.9	51	0	18.4	20	0
	P-38	2.2	20	3	8.1	34	2
	NP-46	36.0	30	0	11.8	16	1
NESS	G-618	17.3	40	2	6.6	40	11
	NE-2	24.7	25	1	24.9	34	1
	NE-4	24.3	16	1	24.3	17	1
	G-3272	69.6	-10	0	24.4	10	0
	G-3273	4.7	69	0	31.7	2	0
Rocky Glades	NP-206	29.2	25	0	23.8	13	0
	R-3110	88.4	-9	0	2.6	13	3
	NP-44	99.8	-27	0	28.4	2	0
Taylor Slough	NTS-1	69.8	-1	0	25.7	3	0
	NTS-14	59.2	6	0	5.3	16	2
	TSB	24.7	62	0	20.9	27	0
	P-37	12.2	21	1	14.3	28	0
Pan Handle	R-158	13.9	49	0	31.7	2	0
	EVER7	45.6	24	0	47.6	14	0
	EPSW	62.6	10	0	50.6	14	0

3.4.1.8 Summary by Variable and Sub-basin

Figure 23 plots the number of sites that are impacted by IOP for each variable. Dry season water levels are most sensitive to IOP, followed by CSSS nesting season dry-down days. Both minimum and maximum dry-down days are less sensitive than the previous two variables, but they show higher frequency than the other variables. Figure 24 displays the rates (in percent) of impacted to total BACI runs by sub-basin. Water levels and hydroperiods at both yearly and wet season intervals are not significantly impacted since IOP was designed to control water levels during the dry season. These four less- or un-impacted variables are excluded in counting the number of impacted sites in Figure 24. In the most sensitive area, WCA-3A, about 40% of BACI runs showed positive change. The sites in Taylor Slough and the Eastern Panhandle showed the second most significant change - more than 20% of BACI results are positive. The impacts on the sites in the remaining three sub-basins are very limited.

In addition, BACI tests were performed with two different sets of regional rainfalls (ENP and WCA-3) in order to investigate the sensitivity of control variable. Figure 25 shows that the results of BACI analyses with both rainfall sets are nearly identical even though the probability exceeding the limiting F-values are changed slightly in each run. This result indicates that the difference of regional rainfalls (either ENP or WCA-3A rainfall) does not significantly affect the result of BACI tests. Finally, Figures 26 – 31 are maps depicting the BACI sites for each analysis, color-coded according to the significance of the change.

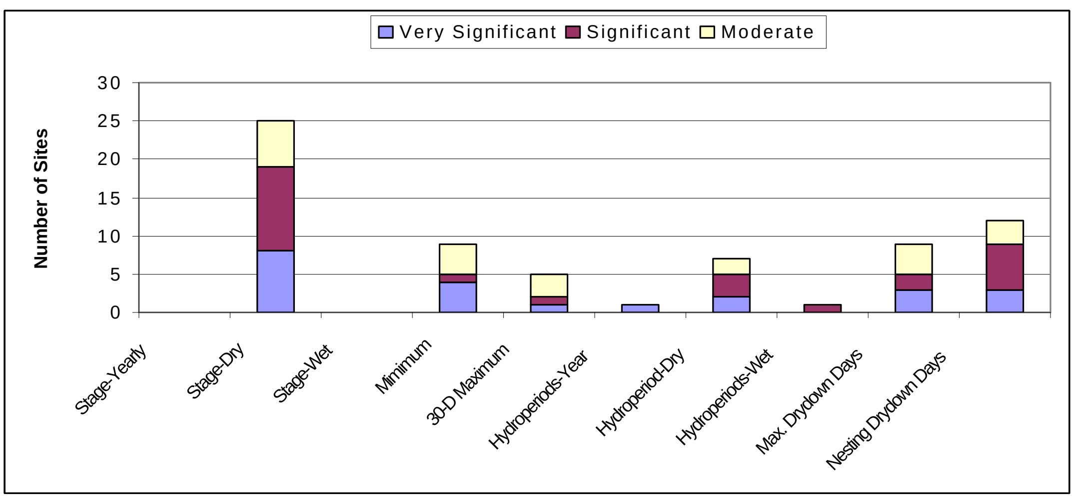

Figure 23. Numbers of IOP impact sites by hydrologic variable, which are counted from the result on

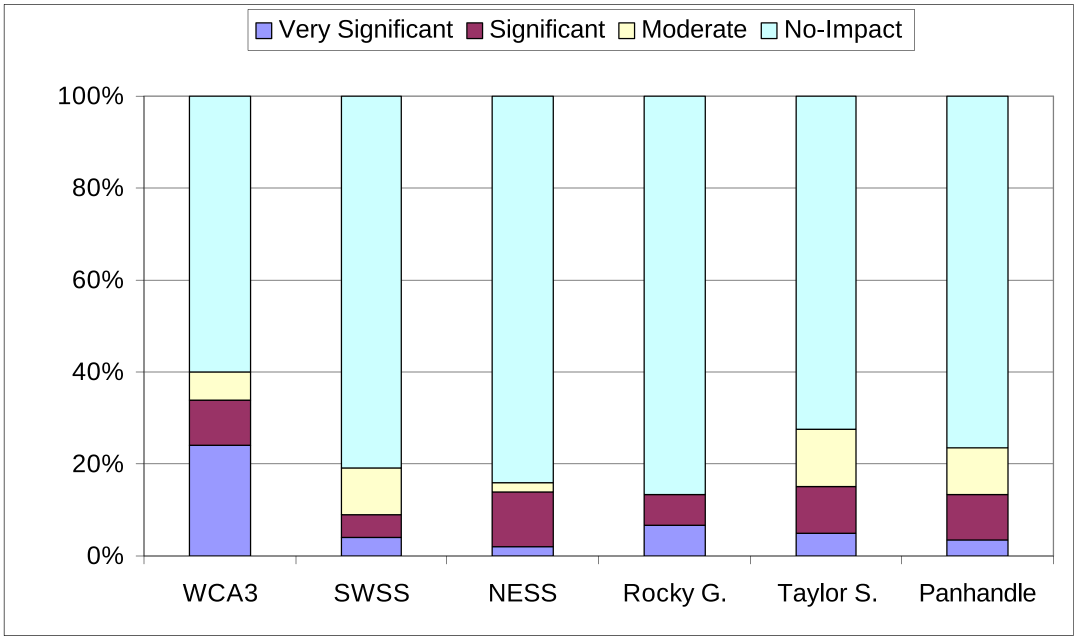

Figure 24. Frequencies of IOP impacts by sub-basin, where the result of all BACI runs for each sub-basin (those for both sites and variables on Table 6) were pooled and counted.

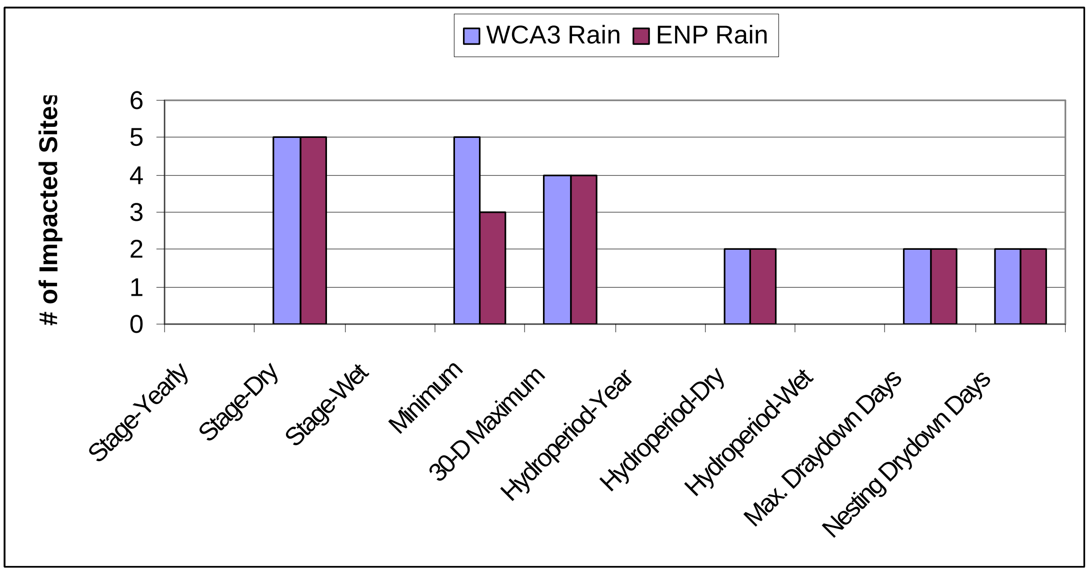

Figure 25. Comparison of BACI tests with two different basin rainfalls, where the numbers of impacted sites (at 15% significance level) in WCA-3A (5 sites) are counted by hydrologic variable.

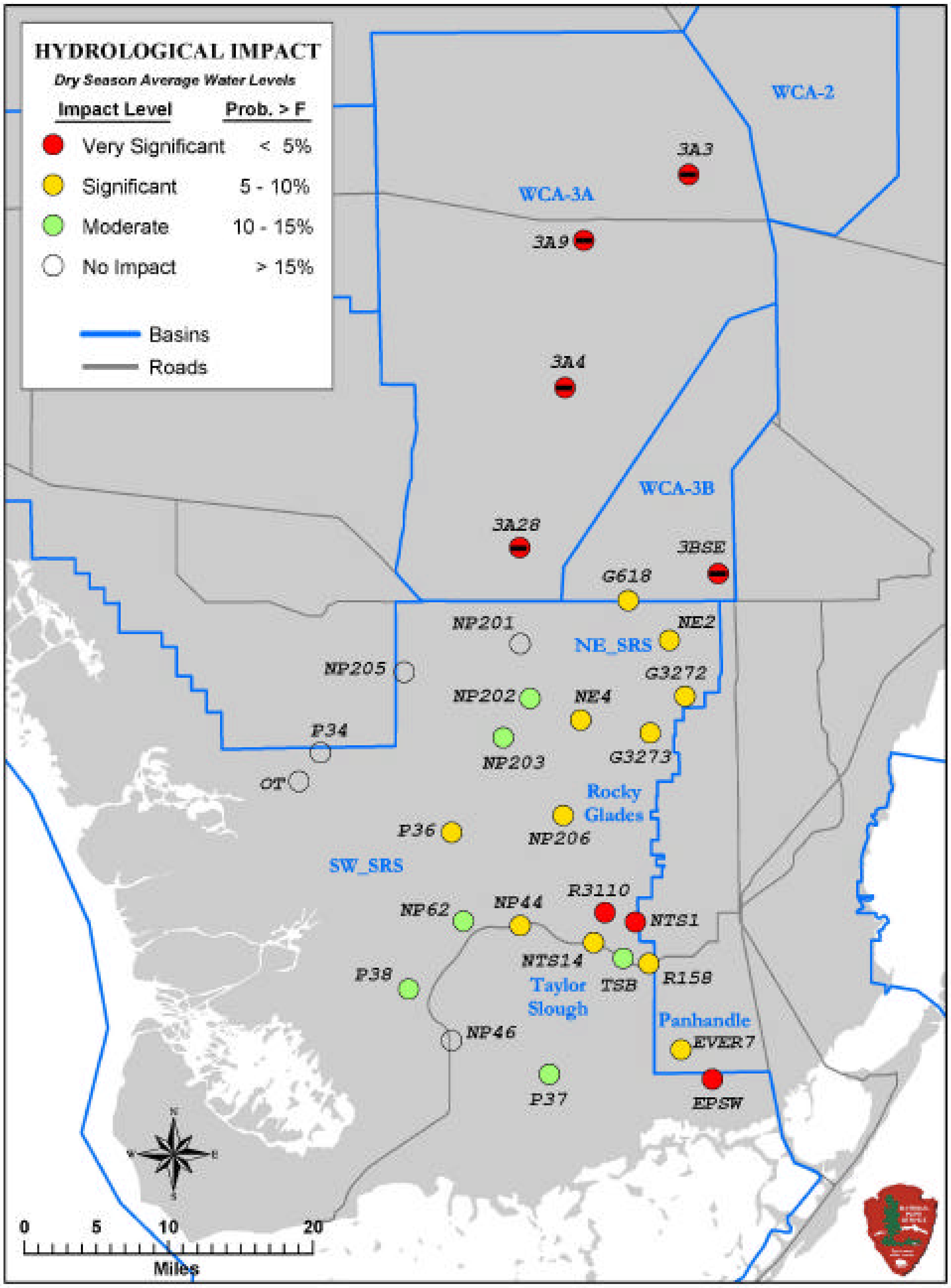

Figure 26. IOP hydrologic impact map - Dry season average water levels. Negative signs ("-") appear within the site symbols to indicate significant decreasing trends, while all other colored sites experienced significant increasing trends during ISOP/IOP as compared with the preISOP period. For example, here, WCA-3A sites experienced lower dry season average water levels during ISOP/IOP than preISOP.

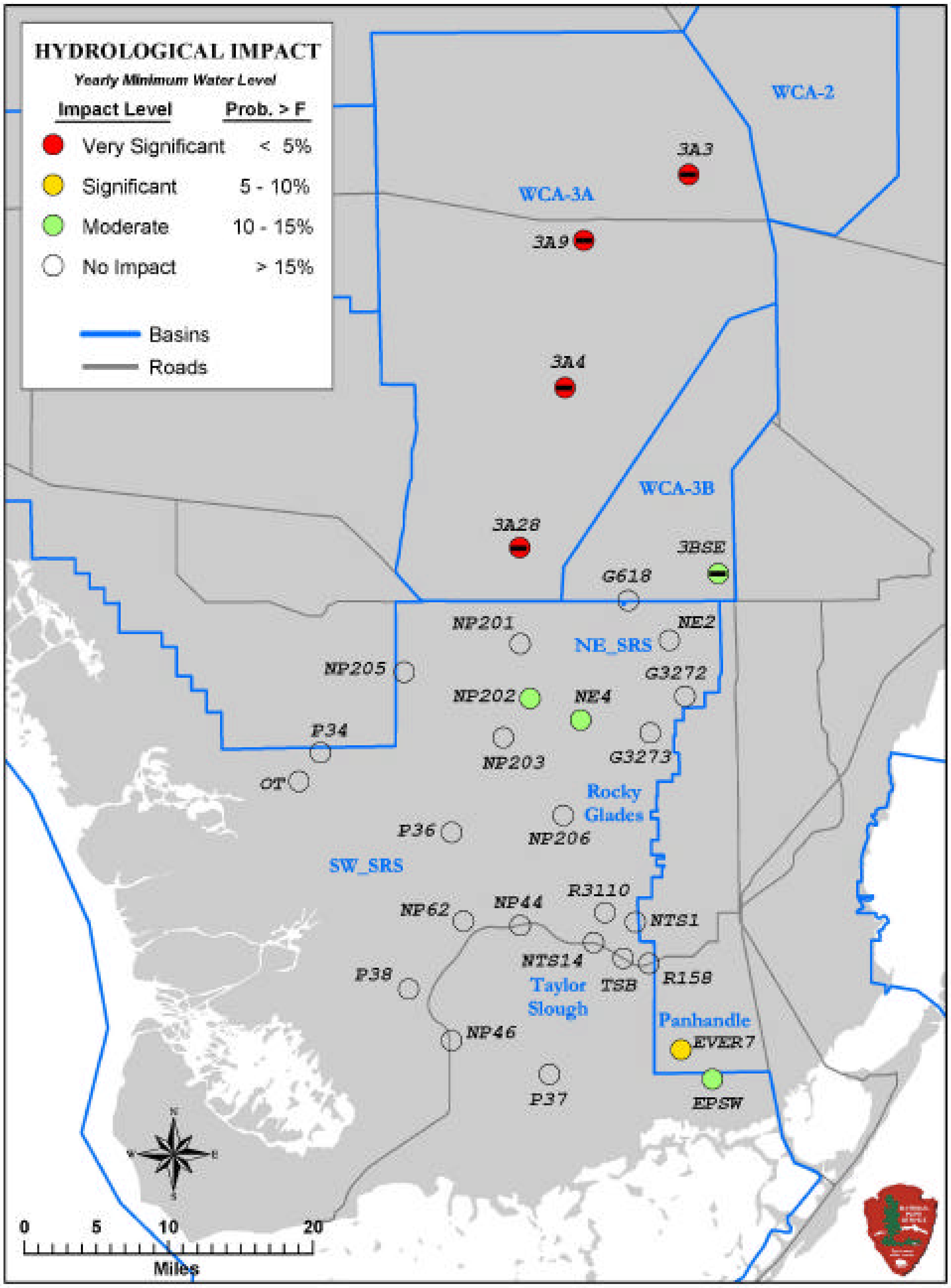

Figure 27. IOP hydrologic impact map - Annual minimum water levels. Negative signs ("-") appear within the site symbols to indicate significant decreasing trends, while all other colored sites experienced significant increasing trends during ISOP/IOP as compared with the preISOP period. For example, here, WCA-3A sites experienced lower annual minimum water levels during ISOP/IOP than preISOP.

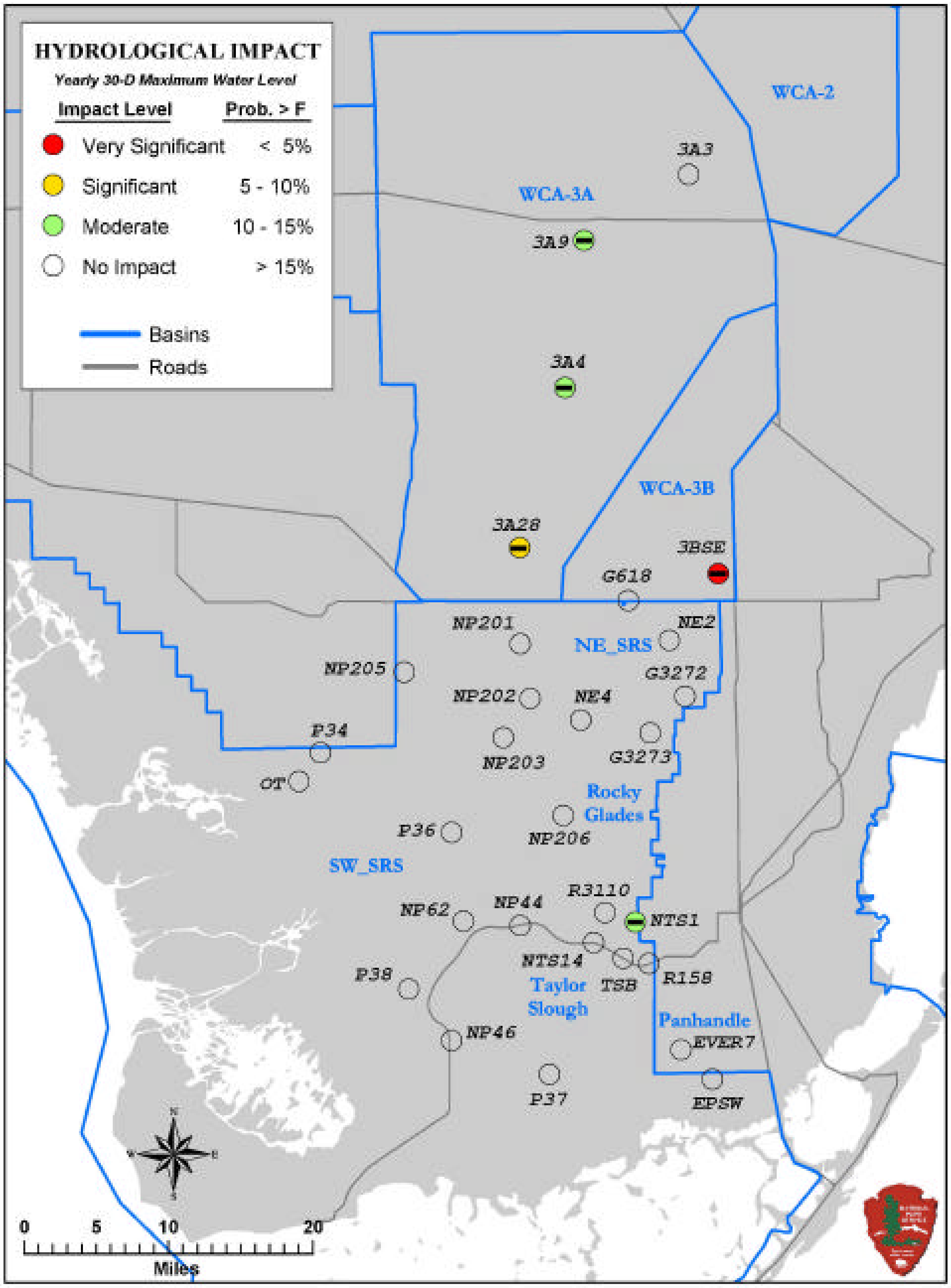

Figure 28. IOP hydrologic impact map - 30-day maximum water levels. Negative signs ("-") appear within the site symbols to indicate significant decreasing trends, while all other colored sites experienced significant increasing trends during ISOP/IOP as compared with the preISOP period. For example, here, several WCA-3A sites experienced lower 30-day maximum water levels during ISOP/IOP than preISOP.

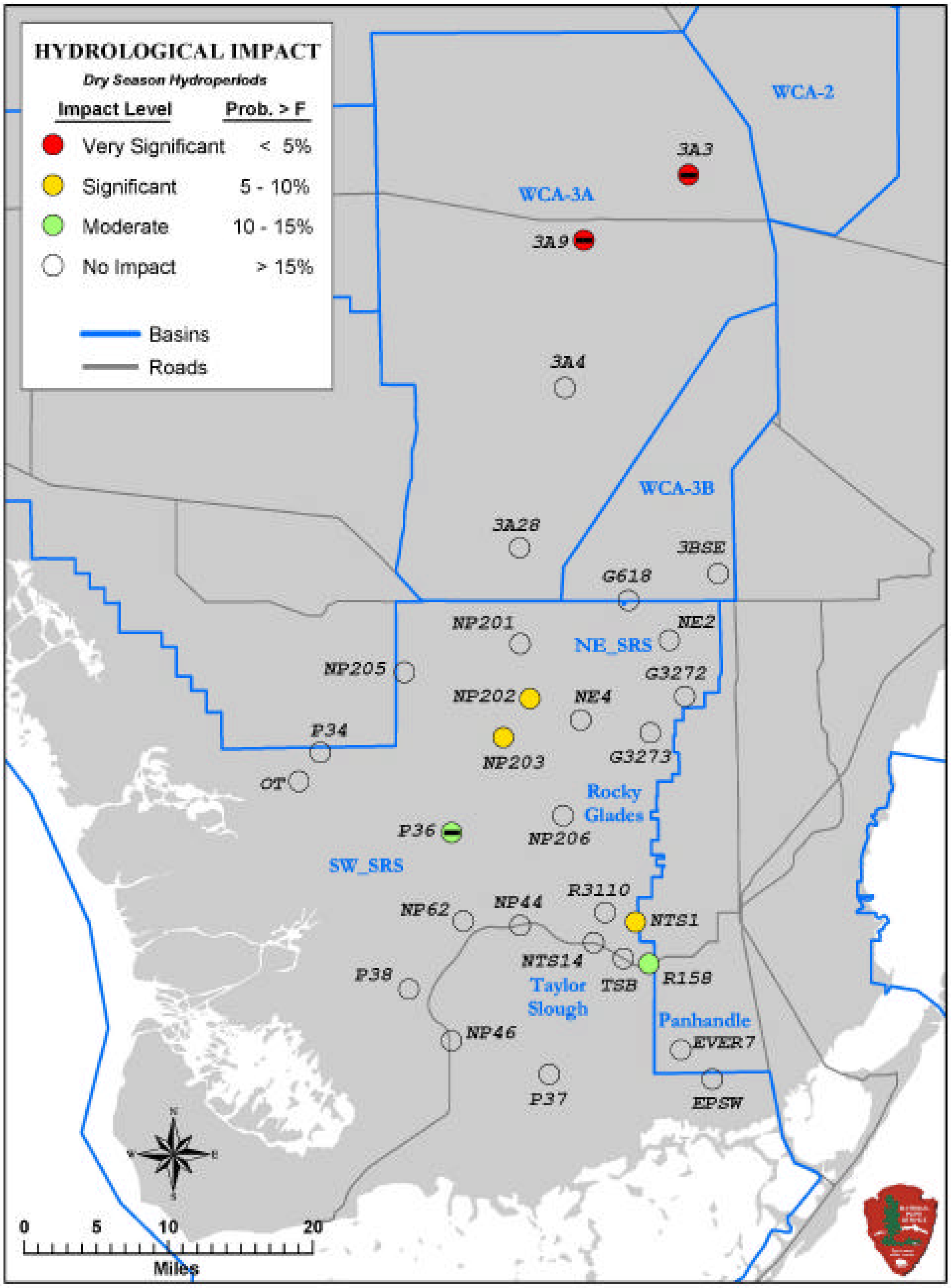

Figure 29. IOP hydrologic impact map - Dry season hydroperiods. Negative signs ("-") appear within the site symbols to indicate significant decreasing trends, while all other colored sites experienced significant increasing trends during ISOP/IOP as compared with the preISOP period. For example, here, two WCA-3A sites experienced shorter dry season hydroperiods during ISOP/than preISOP.

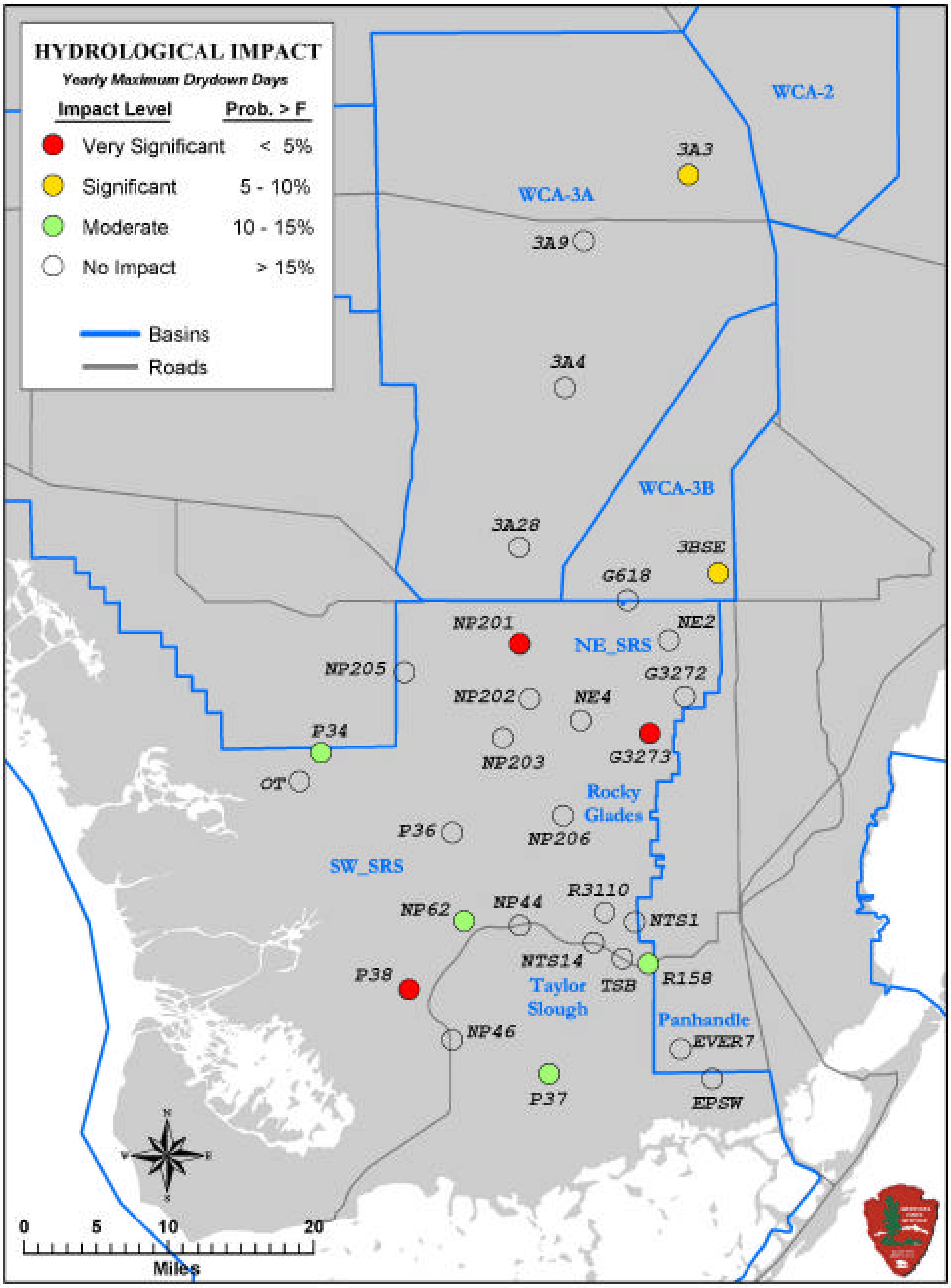

Figure 30. IOP hydrologic impact map - Maximum drydown days. All significant impacts seen are positive, i.e. the number of maximum drydown days was greater during ISOP/IOP than preISOP.

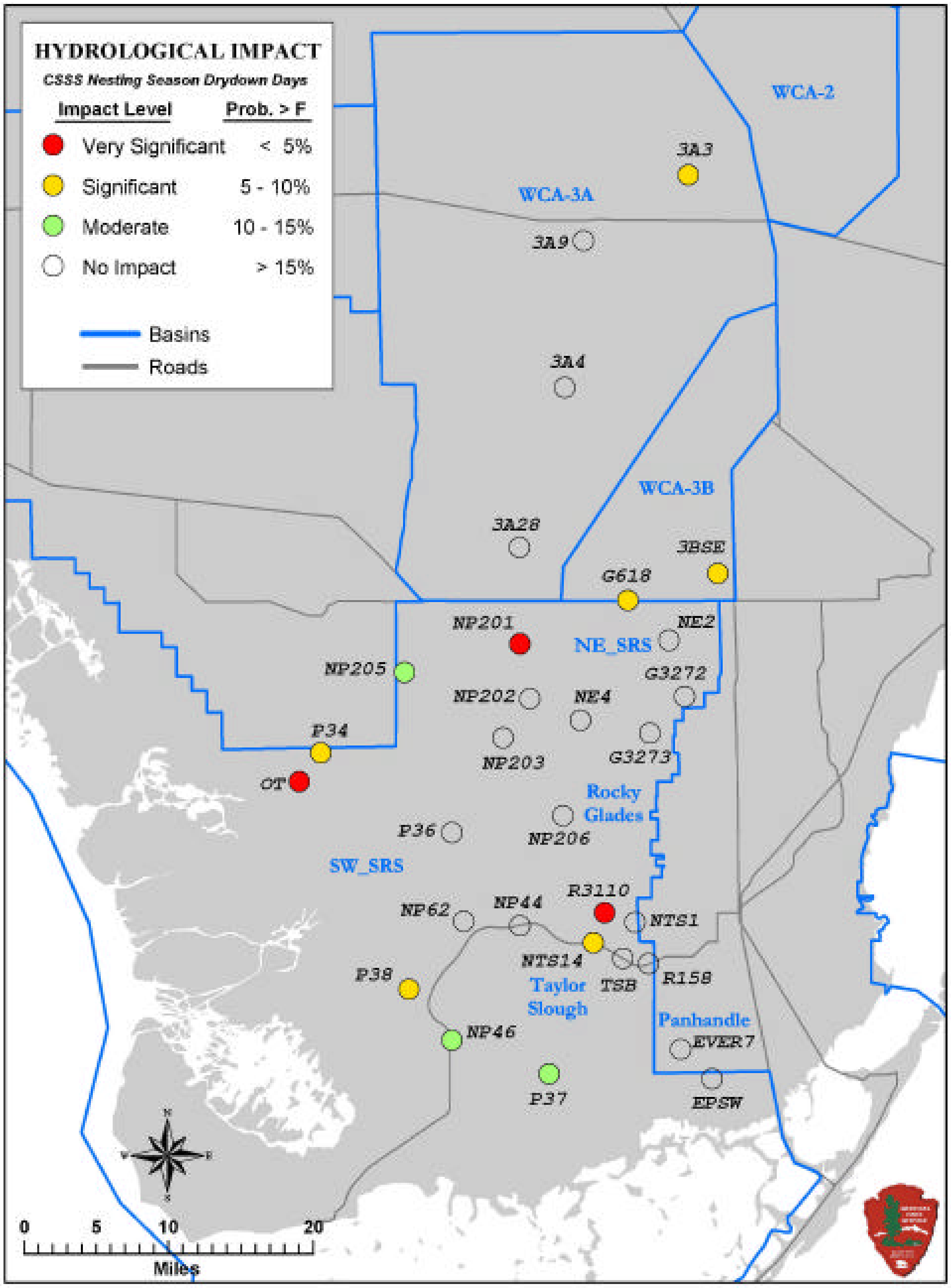

Figure 31. IOP hydrologic impact map - CSSS nesting season drydown days. All significant impacts seen are positive, i.e. the number of CSSS nesting season drydown days was greater during ISOP/IOP than preISOP.

3.4.2 Conclusions from Statistical Analysis

This study performed a total of 300 BACI runs to investigate the impact of IOP on ten stage related hydrologic variables at 30 selected sites in the Everglades. The objective of these statistical analyses is to investigate whether IOP impact on hydrology is significant or not. The goal of this study is to provide the result of hydrologic impact assessments for further investigation of IOP impact on biology. Thus, hydrologic variables and the time scale of data analyses were chosen to match the biological cycle. The result of 300 independent BACI runs reveals that about 23% of the runs showed an increase in variables due to the IOP impact (at a 15% significance level). Excluding four less impacted variables (water levels and hydroperiods of both yearly and wet season terms), the percentage increases to 37% (67 out of 180 runs). IOP impacts on the hydrology are widespread throughout the study area. In terms of the frequency of impacts, WCA-3A is most sensitive to IOP. The Rocky Glades area is least sensitive to IOP. The remaining four ENP areas are sensitive at a medium degree. In particular, the eastern ENP area adjacent to L-31W canal (especially R-3110 and NTS-1) is sensitive to IOP. IOP Impacts are more significant during the dry season than the wet season. Among ten selected hydrologic variables, the IOP impact on dry season water levels is most sensitive, with higher levels in the Park and lower levels in WCA-3A. Number of CSSS nesting season dry-down days is second most significant. In specific, the nesting season dry-down days during the IOP period are increased by nineteen days, while that within CSSS sub-populations is 22 days. These increases indicate that the IOP period is quite favorable to the CSSS species even though these numbers include both rainfall and IOP effects.

The presented BACI analyses are based on the data at yearly intervals with a simplified linear model that does not fully account for the hydrologic variability on a small temporal scale. However, this approach provides an excellent summary statistics on the change of hydrology during the “before” and “after” IOP periods that extend from 1995 to 2002. More importantly, this study applied a uniform method and consistent control variables over the tested sites. This uniformity and consistency allowed for the comparison of relative impacts among sites as well as among variables. It should be noted that the presented results are for site-specific information rather than representing a large area surrounding each site. The statistics presented here are for yearly and seasonal scales that could not tell the variability within year or season.

3.5 Localized Analyses

The above qualitative analysis of canal water budgets, in conjunction with the qualitative analysis of regional water depths, suggested where more focused, quantitative, and localized analyses are required. The following sections address this more detailed analysis.

First, an analysis of the effects of modifying S-12 flows, both upstream and downstream was performed. Second, it was essential to isolate the ISOP/IOP effects in NESS, WCA-3B and the Pennsuco wetlands. Third, as ISOP/IOP was expected to significantly increase hydroperiods in the Rocky Glades with the addition of new structures and reservoirs, an analysis to determine if this happened was essential. Fourth, upper Taylor Slough appeared to have experienced significantly wetter conditions; this was investigated. Lastly, the ISOP/IOP impacts in the lower end of Taylor Slough and Eastern Panhandle, which appear to be small, required further analysis.

3.5.1 Analysis of S-12 Structures and Vicinity

WCA-3A is the second largest (after Lake Okeechobee) multi-purpose reservoir in the C&SF Project. The area is bounded on the east by the L-67A and C canals and on the south by the L-29 levee. It receives inflows primarily from WCA-2A, the Everglades Agricultural Area, Mullet Slough, and the C-9 basin. The main outlet for WCA-3A is the S-12 structures (S-12A, B, C, and D), located along Tamiami Trail, which discharge flow into ENP. In ENP, the primary physical basins receiving water from the S-12 structures are central and western Shark Slough. These features are shown in Figure 32.

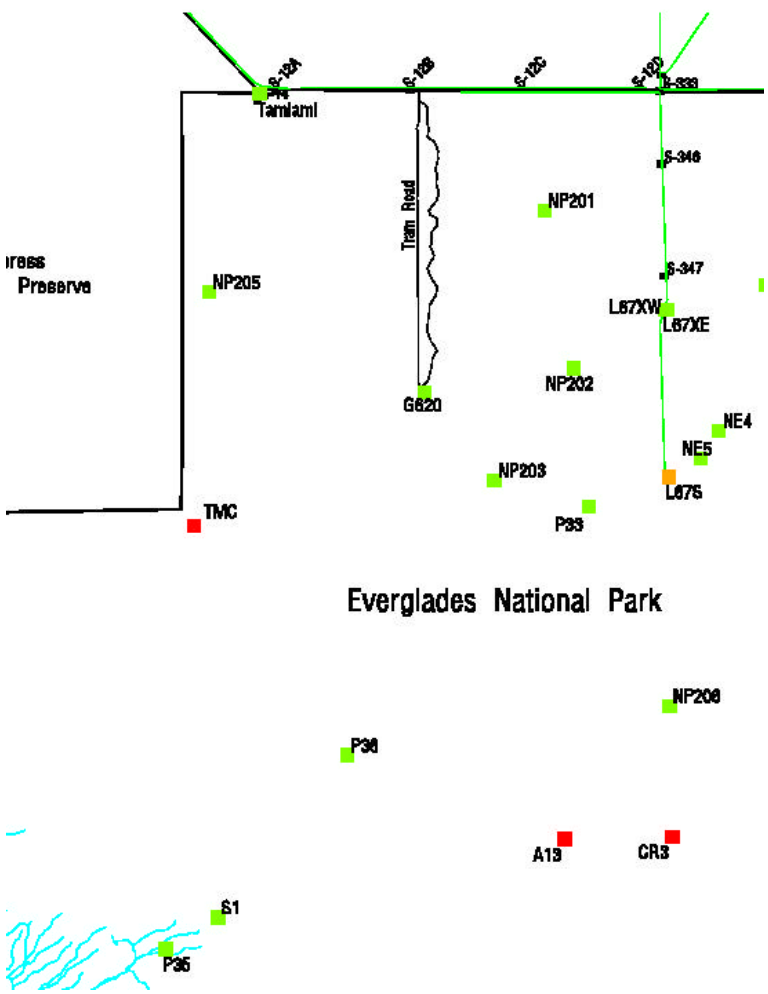

Figure 32. Location map for the vicinity of the S-12 structures.

3.5.1.1 Expectation in ISOP/IOP

The primary objective for ISOP and IOP was to reduce the adverse effects of unnatural volume, timing, and distribution of water over western Shark Slough, which is the habitat for the CSSS subpopulation A. Water levels and hydroperiods in this area are dominated by flow from the S-12 structures. Therefore, the ISOP/IOP called for the reduction of flows directly discharging to sparrow habitat during their nesting period. The expectation was that water levels in western and central Shark Slough would decrease, coupled with a corresponding increase inWCA-3A levels. The effects in WCA-3A and central Shark Slough were not seen as desirable, but a likely consequence of being unable to pass the flows into NESS.

3.5.1.2 Effects of ISOP/IOP in Water Conservation Area 3A

The water levels in WCA-3A are best described by the average of three gauges (3A-3, 3A-4, and 3A-28). This 3-gauge average is used for determining the regulation zone of WCA-3A, which specifies the operations required by water managers. Figures 33 and 34 display the 3-gauge average, superimposed on the regulation zones and show the water levels for 1997 (pre-ISOP/IOP) and 2000 (ISOP/IOP). A new zone, E1, was added to the regulation schedule in March 1999, which mandated that water levels be dropped even lower than previous years in order to reduce dry season ponding in WCA-3A.

Inflows to WCA-3A are from local rainfall and through S-140, S-150, and the S-8 and S-11 structures. The 1997 daily totals (pre-ISOP/IOP) for these inflow structures, along with the total outflows through the S-12s and S-333, are shown in Figure 33. In addition, the three-gauge average stage for WCA-3A is depicted against the regulation schedule. Starting with the wet season, the S-12s were opened and outflows slowly increased as the stage in WCA-3A rose into Zone A and continued into the dry season at which point outflows were scaled back. After Hurricane Irene in 1999 and the incorporation of Zone E1, high outflows continued while inflows were scaled back substantially, and throughout the wet season of 2000 stages remained low in WCA-3A, a condition exacerbated by below normal rainfall (Figure 34). Low stages and the lack of inflows to WCA-3A during the dry season of 2001 coupled with a late-starting wet season to produce very dry conditions in WCA-3A and ENP. These dry conditions occurred again during the dry season of 2002 (Figure 35).

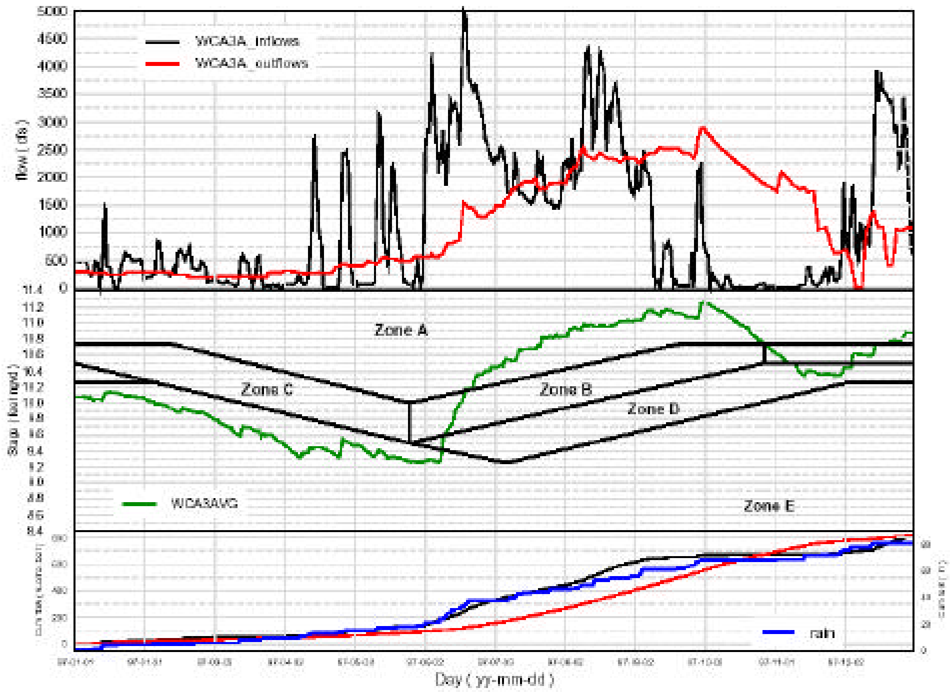

Figure 33. WCA-3A inflows, outflows and stage for 1997

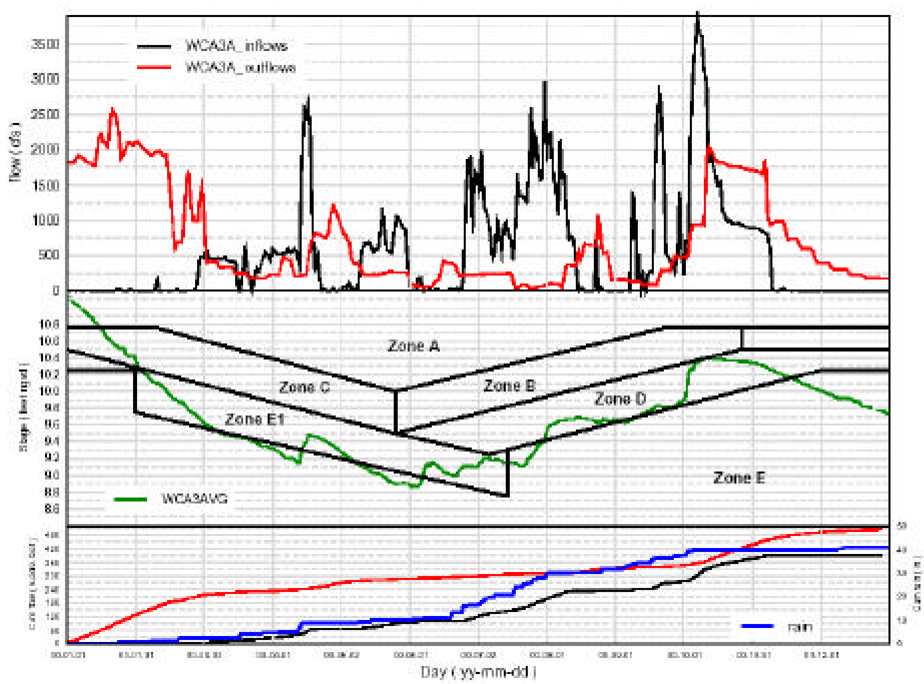

Figure 34. WCA-3A inflows, outflows and stage for 2000

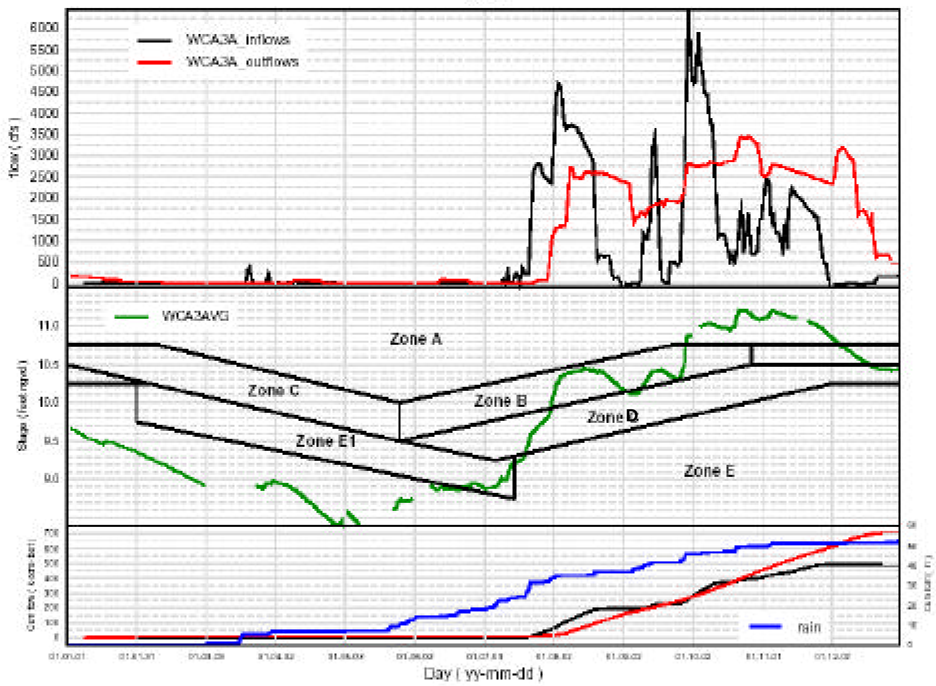

Figure 35. WCA-3A inflows, outflows and stage for 2001

In this section hydrologic analysis is presented to evaluate the impacts of the operational changes that took place in WCA-3A. The ISOP/IOP period included two notable alterations in the WCA3A operational rules. One was the addition of regulatory Zone E1, and the other was restrictions on the use of the western-most S-12 structures during the nesting season of the CSSS. Zone E1 as well as S-12 flow restrictions were actually first implemented in the Spring of 1999 as an emergency response to the USFWS's biological opinion published the previous year.

Regulatory Zone E1 is in effect annually between February 1 and July 15. (See Figure 35.) This zone calls for a regulatory component of maximum practicable releases out of WCA-3A. Prior to the creation of Zone E1, WCA-3A stages in this region would call for only the rainfall plan amount to be passed through the S-12s and S-333, i.e., no regulatory component. As such, it is a potentially significant change in the operations that calls for maximum practicable regulatory releases in the middle of the dry season. At face value, this would tend to accelerate recession rates in WCA-3A, passing dry season flows downstream, which in turn, places downstream receiving waters out of harmony with a rain driven system. Zone E1 was originally developed to provide more dry season storage in WCA-3A so that early wet season rainfall would not cause regulatory releases, particularly through S-12A and S-12B. However, in most cases, it would have no effect, because in almost every year, early wet season rainfall drives water levels at NP-205 above the 6.0 feet nesting threshold well before regulatory releases are called for out of WCA-3A. Data from 1999 through 2003 was used to conduct a brief post audit of ENP's 1999 analysis. The salient data are presented in Table 18.

Table 18. Western Shark Slough

Year	Date NP-205 stage exceeded 6.0 feet	Date WCA-3A exceeded Zone E1	Date WCA-3A exceeded Zone E
1999	May 20, 1999	June 8, 1999	June 17, 1999
2000	June 9, 2000	June 7, 2000	July 31, 2000
2001	June 4, 2001	June 24, 2001	July 21, 2001
2002	May 22, 2002	June 12, 2002	June 20, 2002
2003	April 30, 2003	Not Applicable	May 26, 2003

As with a great deal of analysis conducted on real data, the situation is not completely straightforward. For example, the premise here is that early wet season rainfall causes NP-205 to exceed the 6.0 feet threshold before WCA-3A regulatory releases are required. However, since these data include Zone E1 operations, one could make the feeble argument that Zone E1 is actually working as intended. That is, the reason we do not need regulatory releases until the nesting season is essentially over is because of the positive impact of Zone E1 operations. This argument however is not supportable. Even if we include Zone E1 in the operations, from the table we see that only during June of 2000 did WCA-3A enter Zone E1 before NP-205 exceeded 6.0 feet. And this was only for a period of 2 days until local rainfall essentially ended the CSSS breeding season. In the other years, local rainfall ended the breeding season well before water levels in WCA-3A reached Zone E1 and, of course, much earlier than WCA-3A reached Zone E.

While operations of Zone E1 tend to lower the water level in WCA-3A, S-12 restrictions tend to increase water levels in WCA-3A by decreasing the outlet capacity. The ISOP/IOP dictated that the western-most S-12 structure, S-12A be closed annually on November 1, the next westernmost, S-12B be closed annually on December 1, and the next one, S-12C be closed on January 1 of each year. There are no restrictions on the operations of S-12D. It is important to note that not all S-12 structures are equal. The eastern two, S-12C and S-12D are closer to the center of the slough and thus were sized to discharge substantially more water than S-12A and S-12B. Table 19 is a brief summary of the relative flows through the individual S-12 structures. The units of flow are thousand acre-feet per year; the source is the USGS Water-Data Report FL-02-2A.

Table 19. Summary of annual total and relative flows (in kAF/yr) through the S-12 structures

Statistic	S-12A	S-12B	S-12C	S-12D	Total
Period of Record Avg	96.4	92.6	189.6	189.0	593.5
Period of Record Percentage of Total	16%	16%	32%	32%	

From the data in the table we can conclude that flows through S-12A and S-12B combined are approximately equal to either S-12C or S-12D flows. Therefore, restrictions at S-12A and S-12B combined are more or less equivalent to restrictions on S-12C operations, which begin on January 1.

So what are the impacts of these flow restrictions and the new Zone E1? To answer this question an analysis was performed to estimate the effects of early S12 closure and the addition of Zone E1 to the WCA-3A regulation schedule. Actual stage and storage in WCA-3A were compared to the estimated stage and storage that would result from strict adherence to the regulation schedule.

The following logic was used to make this analysis:

The actual stage (3-gauge average) was used to estimate actual storage volume in WCA-3A on a weekly time step, coinciding with the rainfall plan. The prescribed flow for the S-12s and S-333 was then obtained from the weblished rainfall plan, which includes the rainfall plan amount plus the regulatory amount. While the stage is in Zone A or Zone E1, maximum releases are called for. Because flows through the S-12 structures are typically constrained by tailwater effects, the difference betweenWCA3A stage and the tailwater strongly affects the maximum practicable releases from these structures. During periods in which the S-12 flows are restricted (November 1 – July 15), a reasonable estimate of unrestricted maximum S-12 conveyance must be obtained. It was assumed that the structures could reasonably pass the actual flow volume for that time period, plus an additional amount that would have flowed through the closed structures had there been no restrictions. In order to estimate this forgone potential flow, an average flow volume from each structure, conditional on WCA-3A stage, was calculated. Correlation analysis was performed on each of the restricted S-12 structures (S-12A, B, and C) against the 3-gauge average for a preISOP (pre restrictions) historical period, from 1990 to 1999. The analysis revealed strong correlations between stage and flow, with r-squared values greater than 0.83 in all cases. Thus, for periods during which actual flows plus these estimated potential flows through closed S-12s were below the regulation-plus-rainfall scheduled releases, regulation flow was capped at that actual plus potential value.

The volume difference between actual and scheduled flow was accumulated over the November to October hydrologic year, and, using the WCA-3A stage-storage relationship, an estimated stage was obtained to represent the probable stage, had the regulation schedule been followed exactly. The difference between scheduled releases and actual releases provides a reasonable estimate of the effect of the early closure of the S-12 structures. In addition, this analysis was also performed using the historical regulation schedule, which did not include zone E1 but did have zone D for the months of November and December. This comparison gave an estimate of how the EA-inspired alterations of the regulation schedule affected releases from WCA-3A.

Figures 36 through 38 depict the actual S-12 flows, overlain with the flow and stage differences between actual and regulation schedule based estimates. The upper portion of the graphs shows the actual S-12+S-333 flows less the prescribed regulatory plus rainfall flow. In blue is the comparison between actual observed flows and those which would have resulted from strict adherence to the current regulation schedule; red represents the difference between actual and regulation flows prior to schedule changes (no Zone E1, longer Zone D). Stage differences, shown in the lower portion of the graph, represent the cumulative effect of operations under actual and regulatory conditions over the hydrologic year.

Since the implementation of the EIS, early closure of the S-12 structures resulted in several weeks of releases below those prescribed by the rainfall schedule. However, accumulation of flow differences from November to October showed actual outflows to be consistently higher than those prescribed by either regulation schedule. During the 2000 – 2001 period, actual flows varied little from the schedules, likely due to the generally dry conditions during that time. Zone E1 had little effect, as stages were so low during the three weeks spent in this Zone (mid June), such that the regulation schedule prescribed releases were easily met by minimal flows at S-12D. By the end of the wet season, WCA-3A was actually 0.09 ft below the expected stage under the current regulation schedule and 0.04 ft below that for the preISOP schedule. The 2001 – 2002 hydrologic year showed similar differences at wet season end; actual stage differences were 0.06 below expected for the current schedule and 0.09 ft below that for preISOP. The difference between actual releases and prescribed releases during this period also shows a good example of the effects of Zone E1, which was realized from February 1 to the end of March. It is immediately apparent that the current schedule calls for much greater releases than the preISOP version without Zone E1. Actual releases exceeded the preISOP schedule but were unable to meet those prescribe by the current schedule. This was balanced by late November/early December releases, when stage fell into the region considered Zone D in the preISOP schedule (requiring regulatory releases) but is currently Zone E (prescribes no regulatory releases).

The 2002 – 2003 season was examined where full data was available, up to the end of July. Stages during this period remained in Zone E1 for much of the period, February through May. Despite S-12 closures, actual flows were generally able to meet and even exceed those prescribed during this period. These observed flows were most likely adequate due to low stages through the late dry season, however high rain events were experienced beginning in mid-May and inflows to WCA-3A were significantly increased. The subsequent increase in stage resulted in high scheduled releases, which were not met by the actual flows. Despite these insufficient early wet season releases, Zone E1 period flows surpassed schedule to the extent that by the end of July, WCA-3A stage was 0.04 ft below that expected for the current schedule and 0.10 ft below the preISOP schedule.

This analysis indicates that the effect of S-12 restrictions, which would tend to reduce outflows and increase WCA-3A stage, does not significantly change the annual outflow or stage. In fact, the restrictions are more than offset by the increase in outflows called for with Zone E1 operations. This results in actual stage in WCA-3A being slightly lower than it would have been without the restrictions. While the current regulation schedule does prescribe generally higher annual outflows, overall S-12 closures do not appear to impede WCA-3A discharge to the extent that regulation schedule cannot be met.

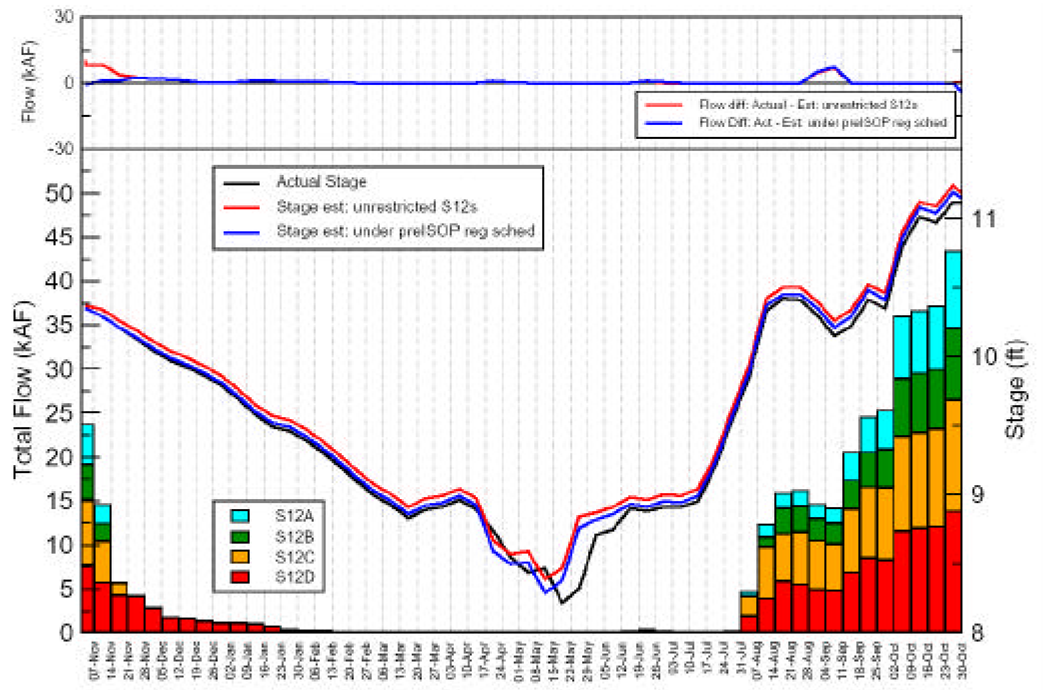

Figure 36. Regulation schedule vs. observed flows 2000 – 2001

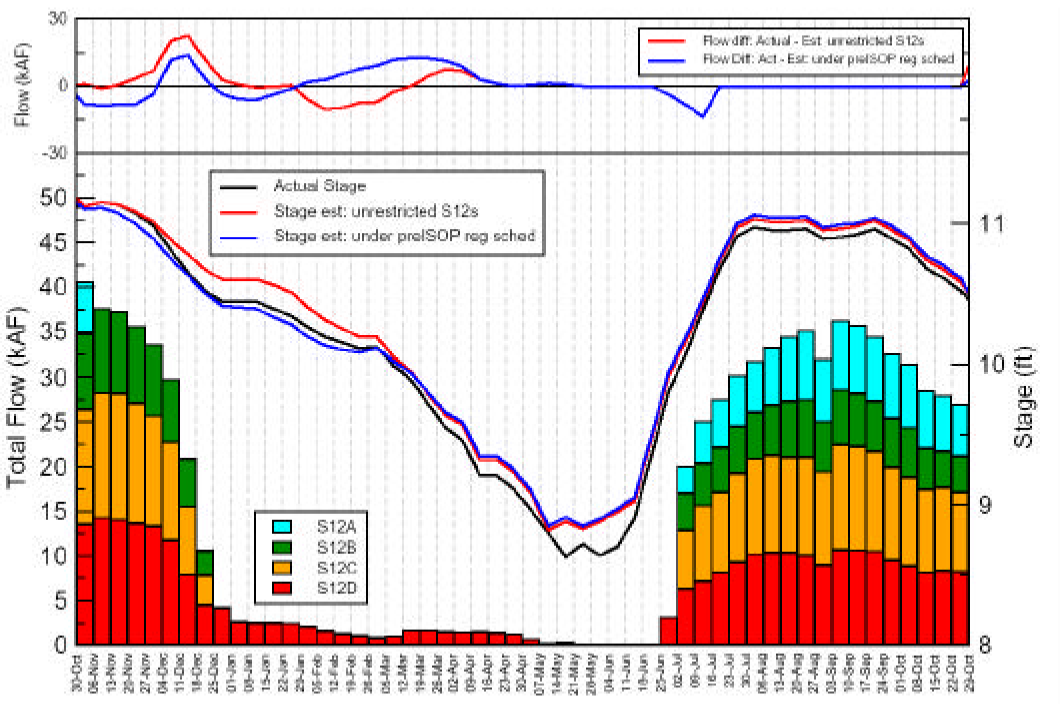

Figure 37. Regulation schedule vs. observed flow comparison 2001 – 2002

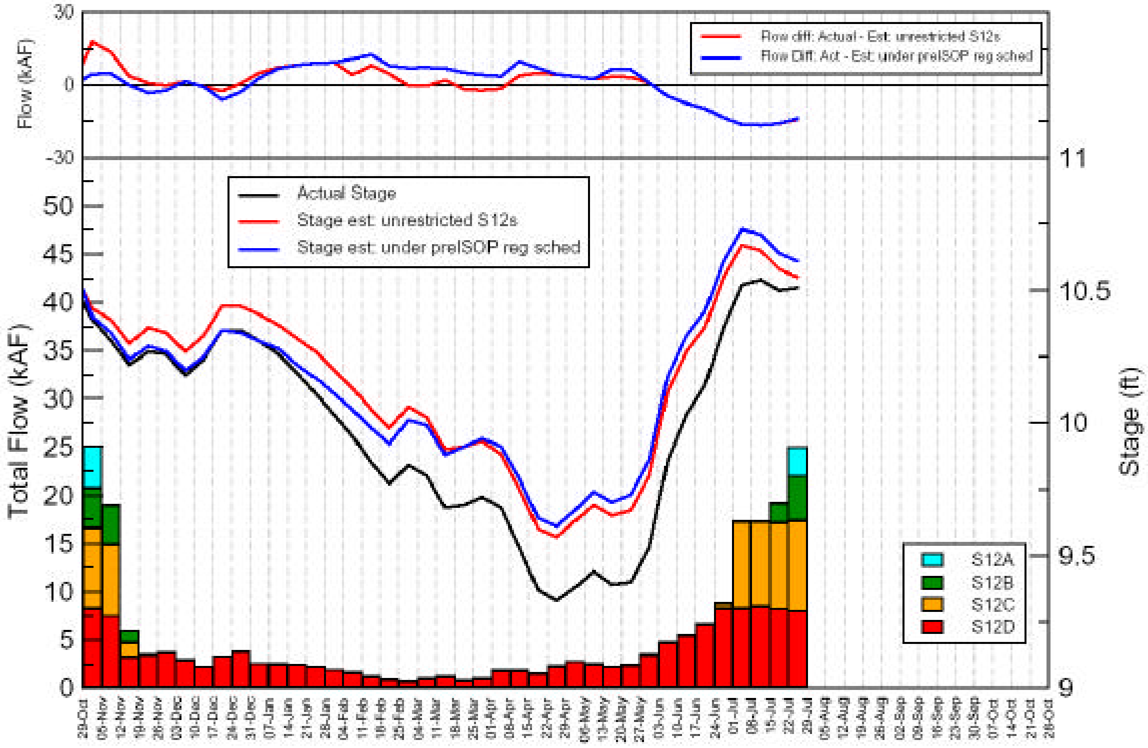

Figure 38. Regulation schedule vs. observed flow comparison 2002 – 2003

3.5.1.3 Effects of IOP/ISOP in Western and Central Shark Slough

This western peripheral wetland or flood plain of Shark Slough has been receiving the majority of the WCA-3A discharges through the S-12 structures. The water levels in western Shark Slough are represented by the gauges NP-205, which is used also as an indicator of conditions in the CSSS Population A habitat, and P-34 which shows the water depths for the far western region of the floodplain of Shark Slough, bordering Big Cypress. Figure 39 shows plots of the water levels for the study period with the horizontal dashed lines representing the ground surface elevation at each station. Average western Shark Slough water levels are reduced after implementation of IOP, and levels are seen to stay continuously below ground surface for a longer period of time.

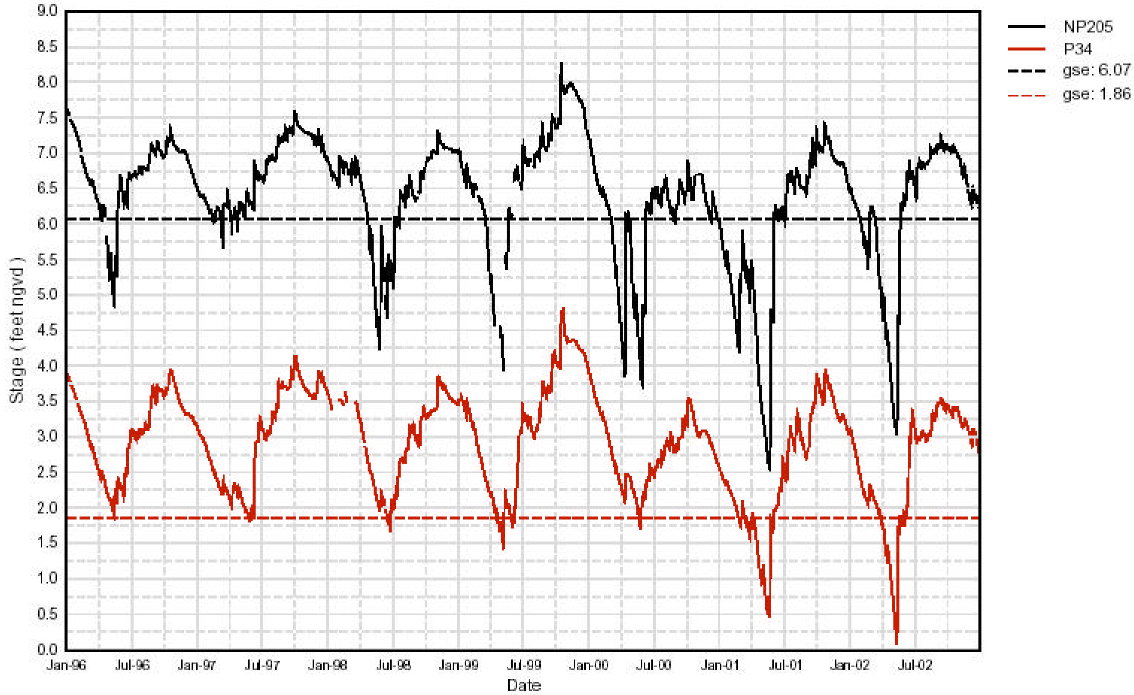

Figure 39. Northwest Shark Slough water levels: NP-204 and P-34.

South of the S-12 structures into the main region of Shark Slough the water levels shown in Figure 40 define the path south into the tidal region north of the Broad River Basin. During the average wet season of 2000, little water was brought into WCA-3A. The resulting reduced outflows, coupled with the closure of the S-12 structures during the dry seasons of 2001 and again in 2002, caused the water levels at NP-201 to drop significantly and set up a reverse gradient between P-33 and NP-201. Farther south, the water levels at P-36 still show the lower water depths, which gradually diminish in magnitude, as seen at P-35, where tidal influences limit the effect of the lowered water depths.

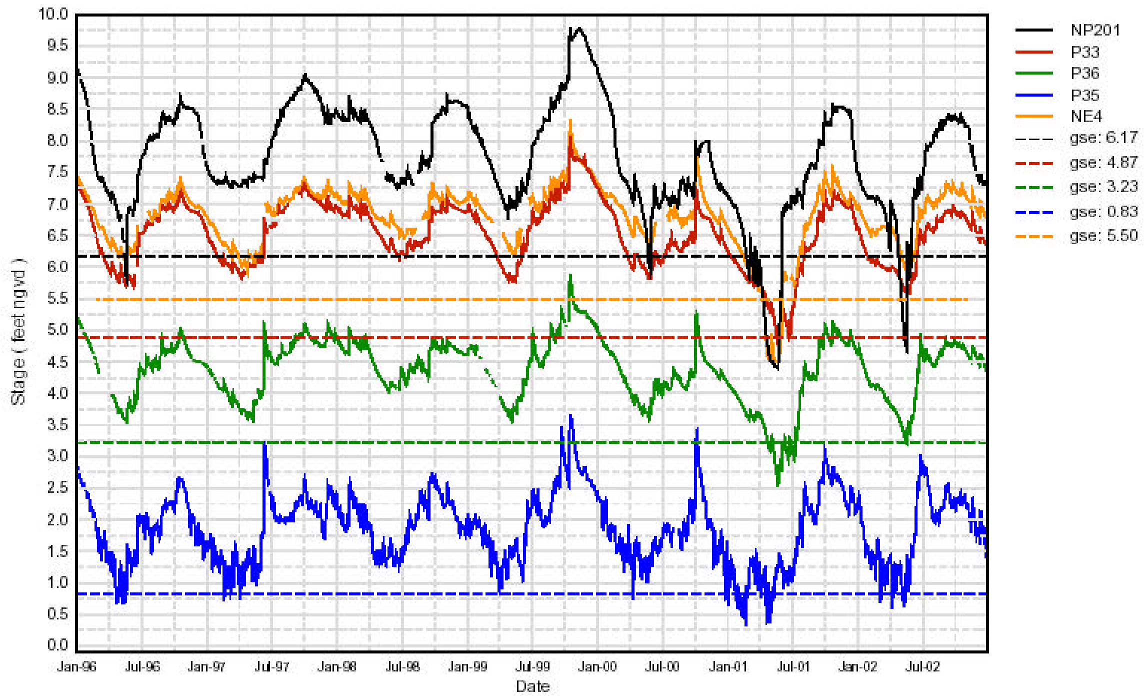

Figure 40. Central Shark Slough water levels: NP-201, NE-4 or P-33, P-36 and P-35

3.5.2 Water Conservation Area 3B and Northeast Shark Slough

WCA-3B is an Everglades wetland bounded on all sides by C&SF Project levees and canals. On the east, the L-30 levee, part of the Eastern Projective Levee System, is considered the boundary between the remnant Everglades and the Lower East Coast. On the south, L-29 levee, running parallel to Tamiami Trail, forms a surface water barrier between WCA-3B and NESS. Two structures, S-355A and S-355B, make it theoretically possible to pass surface flows between WCA-3B and NESS, but these have yet to be operated. On the west and north, L-67A and L-67C levee and canals run generally perpendicular to the historical direction of sheetflow, acting as a dam across the Everglades.

The area known as NESS, shown in Figure 41, was incorporated into ENP by the 1989 Everglades National Park Expansion Act (PL 98-181). NESS, is bordered to the north by Tamiami Trail, and sheetflow from the north is cut-off by the L-29 levee at the southern end of WCA-3B. On the east, the L-31N levee confines the surface water in the slough, and the L-31N borrow canal acts to drain seepage from the area. Since no surface water outflow occurs from WCA-3B, the water deliveries to this area are made via structure S-333, a conduit providing water from WCA-3A to the L-29 borrow canal. Culverts under Tamiami Trail pass flow directly into the wetlands of NESS. The flows into NESS are generally small and constrained by several factors, including the indicator gauge G-3273, which triggers the closure of S-333, generally when water levels at the gauge exceed 6.8 feet. NESS is primarily a rainfall driven system, with some small surface water inflows from S-333. The result is that water levels often look like a flat pool with low relief, indicating very little sheetflow. The primary gradients, which determine the direction of surface and groundwater flow, are primarily to the east and southeast, rather than the southwesterly direction that the topographic gradient would indicate.

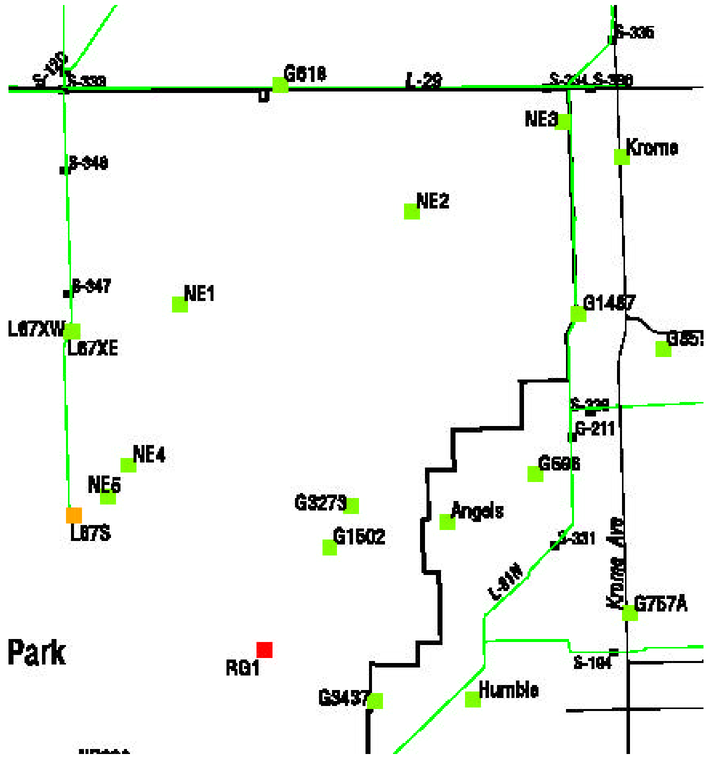

Figure 41. Location map for Northeast Shark Slough, Water Conservation Area 3B.

3.5.2.1 Expectation in ISOP/IOP

In the RPA in the Biological (USFWS, 1999), an objective was to put water that was currently and unnaturally flowing over western sparrow habitats into NESS. This was expected to have benefits to both the western and eastern habitats, which would both experience hydrologic conditions more consistent with their evolutionary history. The expectation in ISOP/IOP was that NESS would become wetter, although the primary mechanism was by removal of the lower half of L-67ext rather than by increased surface water inflow.

WCA-3B was not expected to have any significant effects, either positive or negative, from the ISOP. There is no issue related to the CSSS related to WCA-3B.

3.5.2.2 Analysis of the Effects of ISOP/IOP

In reviewing the canal water budgets in Figures 7 through 14, it would appear that L-30 and L-31N operations have been significantly modified by ISOP/IOP. S-335 flows appear substantially higher, as do S-338. If so, there is a potential for significant and adverse consequences to WCA-3B, NESS, and the Pennsuco wetlands.

To understand the possible effects of S-335 operations and how they might have changed, some historical background is in order. Prior to the C&SF Project, the coastal ridge formed the eastern boundary of the Everglades. Since the construction of the C&SF project, the challenge of flood control has consistently been to drain water from the interior over the hump of the coastal ridge to tide. Since the flood control system relies heavily on gravity as the driving force, the further from tide, the more difficult it is to provide flood protection. One of the interior basins well known for being flood prone (because it is far from tide) is known as Area B. Area B (Figure 41), is bounded on the north by the C-6 (Miami Canal) on the south by C-1 (Black Creek), on the east by S.W. 77th Avenue and on the west by Levee 30. Original C&SF documents as well as many successive analyses have conceded that it is simply not feasible to provide 1-10 flood protection for Area B. S-335 connects the southwest corner of Area B to the SDCS. S-335 replaced S24 and was completed in 1982 as part of the SDCSSystem.

Since its initial operation in 1983, S-335 has been used primarily for dry season water supply to the SDCS for agricultural and environmental water supply. Occasionally, S-335 would also pass flows from either Lake Okeechobee or WCA-3A in the early wet season if capacity was available in the SDCS. During these few events, S-335 was passing S-337 flows that did not seep east. Since implementation of the ISOP/IOP, S-335 has been operated routinely during the wet season in an effort to keep the L-30 canal stage below 6.0 feet. Table 20 shows wet season total flows at S-335. We can see from the table that wet season flows were infrequent before 2000. Further, if the early wet season water supply flows are ignored, it can be seen that S-335 was never used during the middle to late wet season until ISOP/IOP. Wet season flows in 2000 and 2002 are substantial portions of the total annual flow. For the years 2000 and 2002, the wet season flows represent approximately one-half of the dry season deliveries.

Further, if we look at the flow response to basin rainfall using a double mass curve Figure 42, we can get another look at operational changes over the period of record. A double mass curve is a plot of the cumulative flows vs. the cumulative rainfall. Typically the flow response to rainfall is linear. Changes in the slope of the double mass curve indicate a change in the operations of the structure. From the double mass curve it appears that for the period starting in 1993 there have been two significant changes in the rainfall-flow response. It appears that S-335 flows are increasing relative to rainfall, i.e., S-335 is increasingly used to drain the L-30 basin.

Table 20. Flow volumes at S-335 by year.

S335 Total Flow (acre-feet x 1000)			
Year	**Jun - Oct**	**Jul – Oct**	**Aug - Oct**
1984	0.0	0.0	0.0
1985	0.0	0.0	0.0
1986	4.5	0.0	0.0
1987	39.8	7.9	0.0
1988	0.0	0.0	0.0
1989	32.3	0.0	0.0
1990	0.0	0.0	0.0
1991	0.0	0.0	0.0
1992	6.0	0.0	0.0
1993	26.9	0.0	0.0
1994	0.0	0.0	0.0
1995	1.5	0.0	0.0
1996	0.0	0.0	0.0
1997	0.0	0.0	0.0
1998	21.8	4.1	0.0
1999	1.5	1.4	1.4
2000	41.6	38.8	30.7
2001	6.9	6.7	3.4
2002	30.2	26.8	22.5

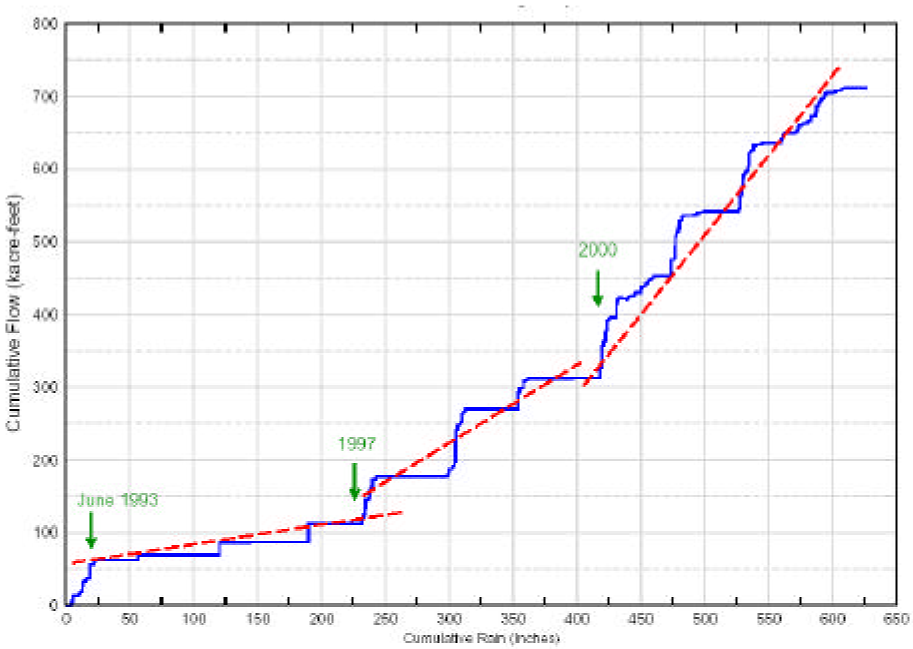

Figure 42. Double Mass Curve of Rainfall versus S-335 Flows

The S-338 structure has also undergone a significant increase in flows. Table 21 compares the annual flow volumes past S-338 and annual rainfall totals, along with their relative ranks in the period from 1980 to 2003. There is a large disparity between the rank of rainfall and flow at S-338. The total flow between January 1, 2003 and September 28, 2003 was the highest ever recorded. All of the ISOP/IOP years rank well above where one would expect relative to the rainfall rank.

It would appear that one C&SF Project operation that was implemented under ISOP was to significantly increase outflows from the L-30 via S-335 and L-31N via S-338. These have no direct relationship to providing a benefit or mitigating a disbenefit for the CSSS. They were likely implemented for some other purpose; the mostly likely reason is to improve flood protection, as the flows primarily occur in the wet season.

These increased outflows from L-30 show up clearly as an adverse impact in WCA-3B. Figure 43 shows the water levels for station 3B-SE, 3B-2 and 3B-3. After Hurricane Irene, use of S-335 and dry periods in the 2001 dry season eliminated storage in the system and water levels plummeted, causing severe dry-downs in WCA-3B. The effects of the increased S-335 flows are clearly evident here. Minimum water levels in southeastern WCA-3B dropped somewhere between 1.5 and 2.0 feet below those in similar years, and generally lower water levels throughout the area. Moreover, the recession rates in the late wet season also increased dramatically. Note how much sharper the surface water recession rate becomes in the ISOP/IOP period; this is indicative of a drainage effect that previously did not occur.

Table 21. Table 1 Comparison of S-338 flow volumes and rainfall

	S-338 Volume (kAF)	Rank	Rainfall (in/year)	Rank	Rain Rank - Flow Rank
Dec-80	17	20	40.78	22	2
Dec-81	26	19	59.54	10	-9
Dec-82	56	15	56.04	12	-3
Dec-83	83	8	68.4	3	-5
Dec-84	64	13	54.92	14	1
Dec-85	12	21	50.67	18	-3
Dec-86	40	16	52.43	17	1
Dec-87	32	18	55.93	13	-5
Dec-88	62	14	52.96	15	1
Dec-89	12	22	43.34	21	-1
Dec-90	0	24	52.93	16	-8
Dec-91	65	12	63.52	6	-6
Dec-92	12	23	50.24	20	-3
Dec-93	34	17	58.22	11	-6
Dec-94	68	11	84.74	1	-10
Dec-95	135	4	69.58	2	-2
Dec-96	91	7	68.14	4	-3
Dec-97	72	10	61.98	7	-3
Dec-98	115	5	50.67	18	13
Dec-99	150	3	65.06	5	2
Dec-00	98	6	32.3	24	18
Dec-01	82	9	61.27	8	-1
Dec-02	157	2	61.18	9	7
Sep-03	164	1	38	23	22

Figure 43. Water levels in WCA-3B, gauges 3B-SE, 3B-2 and 3B-3

NESS also appears to be affected by operations in the L-30 and L-31N canals during ISOP/IOP. Figure 44 shows water levels at the central NESS gauge NE-1 and gauge NE-3, located near the intersection of L-29 and L-31N.

The increases due to local rainfall caused by Hurricane Irene and the No-name storm are relatively brief and drain out quickly as shown by the plots of NE-1 and NE-3. G-3273 is located on the eastern edge of the slough, near the developed 8.5 SMA. Water levels at G-3273 are generally below ground surface, causing this gage to experience large fluctuations in water level relative to NE-1 and NE-3. The drainage operations of the S-331 pumps also contribute to the fluctuations by pulling large quantities of water from the wetland region. The precipitous drop in water level during the dry season of 2001 is most likely an indication of the lack of dry season water availability following the draining of WCA-3B. S-335 operations also lowered regional water levels in WCA- 3B, Pennsuco, Bird Drive and NESS basins. The effects are seen in the dry seasons of 2001 and 2002 not only on the peripheral wetlands of NESS, but deep into the slough itself, at NE-1 and other slough gauges.

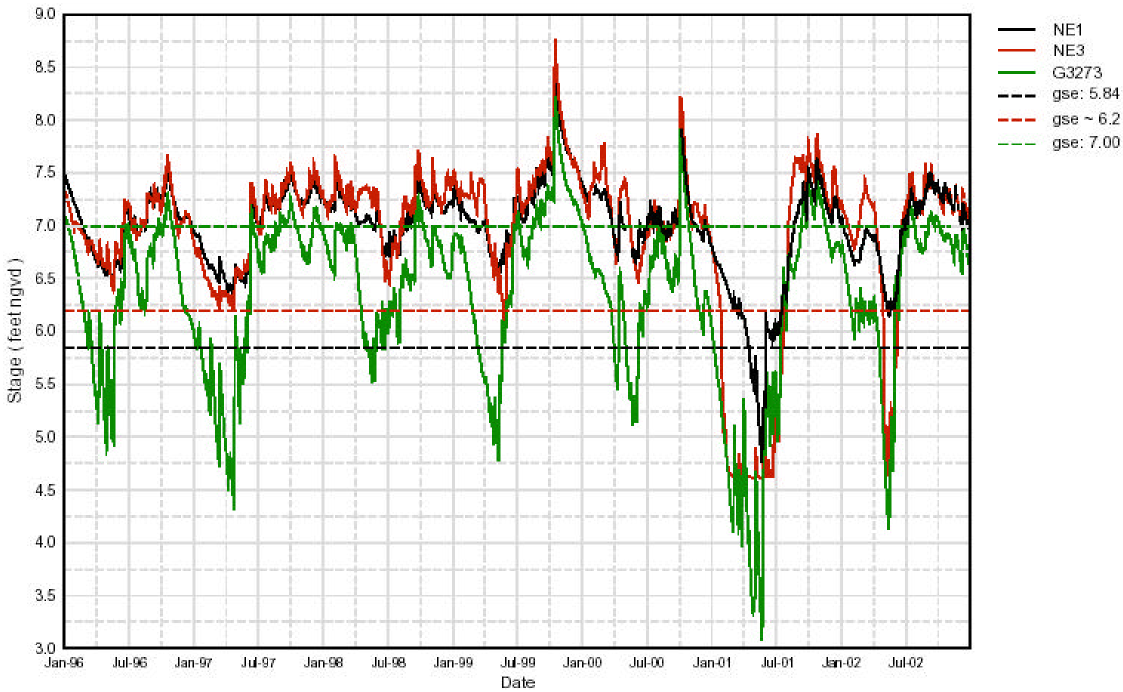

Figure 44. Water levels in NESS: G-3273, NE-1, and NE-3

The apparent decrease in water levels and hydroperiods in NESS was probably not the result of a reduction in direct S-333 discharges, but it could be partially explained by the decrease in S-12 flows. The bar chart in Figure 45 shows the flow into Shark Slough and the proportion delivered into western Shark Slough and eastern Shark Slough. The western Shark Slough deliveries are made through the S-12 structures while the eastern deliveries are made through S-333. The flow into eastern Shark Slough is determined by subtracting the flows out of L-29 at S-334 from the flows into L-29 at S-333. While the proportion of the flow going into NESS has increased, the total flow amounts have decreased. The 2000-2001 Shark Slough flows were extremely low, although wet season rainfall was nearly average. Again, in 2001-2002 the wet season was extraordinarily wet and yet the total flows to Shark Slough are greatly reduced compared to Test 7 flows. Although the 2000-2001 dry season was unusually dry, this was not the case for the 2001-2002 dry season. In 2002-2003 the total flow volume into Shark Slough has increased, but the ratio of eastern to western flow has shifted back to the west. It would appear the flow into Shark Slough continues to be dominated by the S-12 structures. One very likely reason why reduced S-12 discharges result in lower water levels in NESS is that water levels downstream are reduced, increasing the surface water gradients out of NESS.

The increased L-31N outflows also probably played a role in the observed generally lower water levels. According to Figures 7 through 14, net seepage from NESS into L-31N during ISOP/IOP years was very similar to that observed from the much wetter prior period. Figure 46 suggests that, during ISOP/IOP, the majority of seepage from NESS into L-31N came in the wet season, which typically only happens in extremely wet years.

Another possible factor in the observed behavior of NESS is the removal of the lower portion of L-67ext. Unfortunately, almost no water level information is available that could shed direct light on the resultant hydrologic changes. In our opinion, it is unlikely that, in and of itself, removal of the levee resulted in lowered water levels in NESS. First, water levels appear to decrease in NESS beginning in 1999, and the levee wasn't removed until 2002. Second, removal of the levee does very little to change the quantities of water past Tamiami Trail. However, by making it easier to equilibrate water potentials between western Shark Slough and NESS, the effects of lower water levels in western Shark Slough could more easily propagate into NESS, and that could have had an effect.

3.5.2.3 Summary of ISOP/IOP Effects

The ISOP/IOP operations appear to have unintended and adverse effects in WCA-3B, most likely because of increased outflows from L-30 via S-335. NESS also did not respond as expected. The most likely explanations for this are increased seepage losses resulting from L-31N operations and a residual effect from significantly reduced S-12 discharges. No information was available that could help determine the effects of the removal of the lower portion of L-67ext.

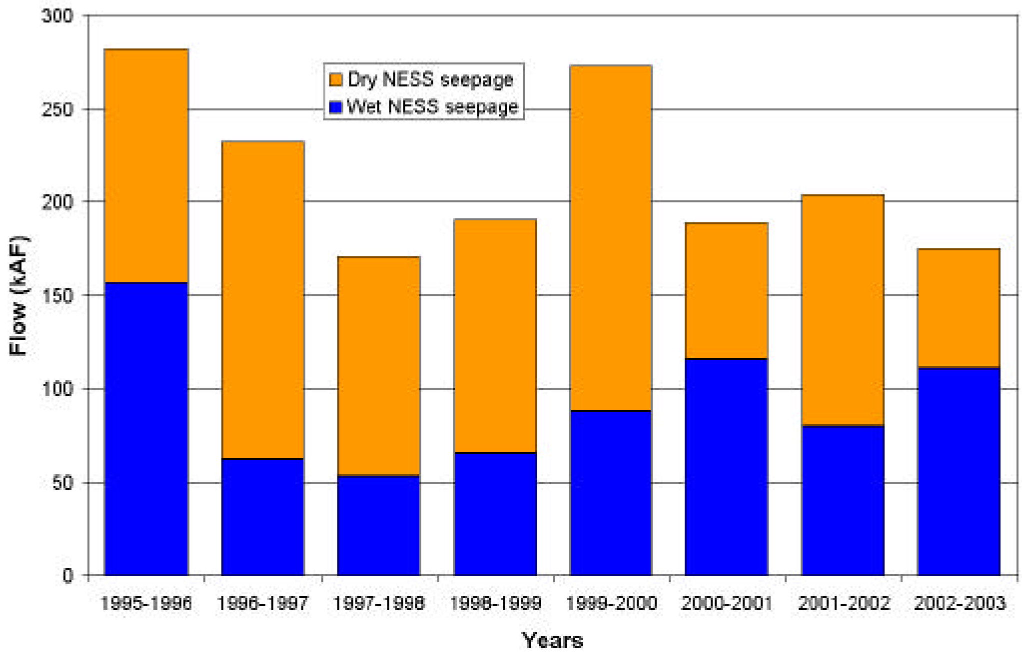

Figure 45. Distribution of Shark Slough inflows compared to L-31N inflows.

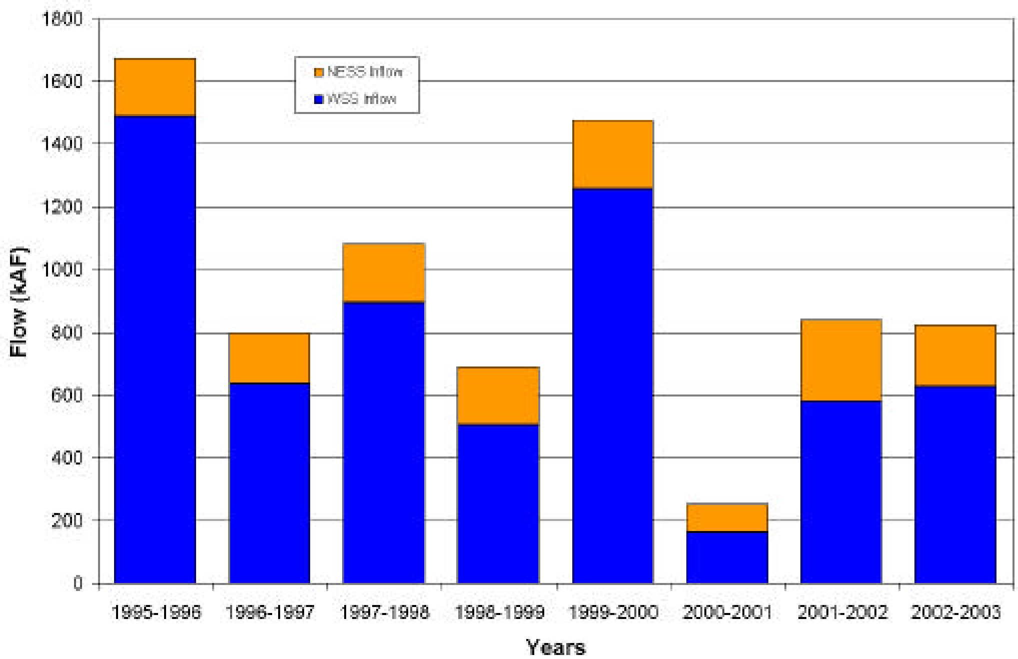

Figure 46. Wet and dry season seepage out of NESS

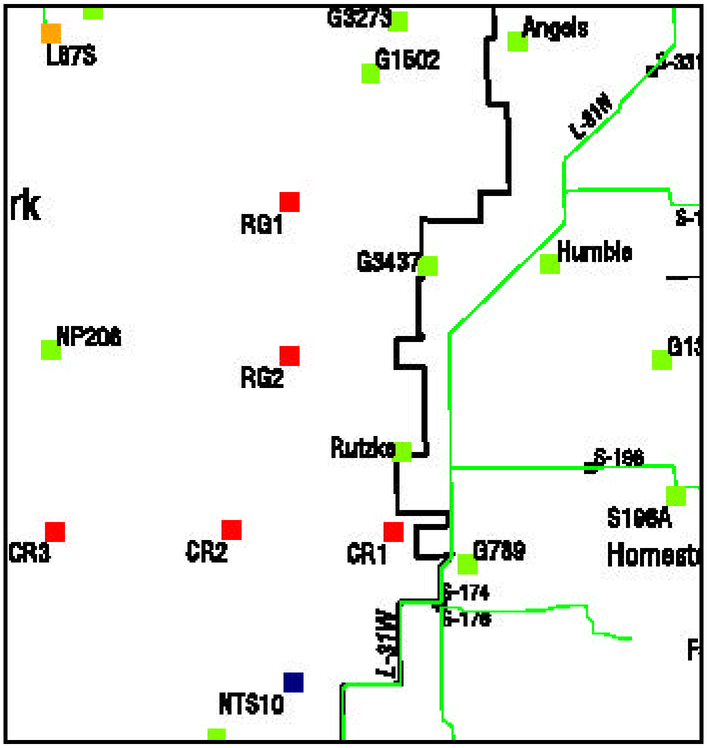

Figure 47. The Rocky Glades Area

3.5.3 Rocky Glades

The floodplain to the east of Shark Slough is the Rocky Glades, a higher elevation outcrop of pinnacle limestone and marl, which historically extended into the developed areas east of L-31N (Figure 47). The eastern boundary of the Rocky Glades is a hydrologically complex area due to the effects of the C&SF Project. The 8.5 Square Mile Area and the former East Everglades agricultural areas exist west of the Eastern Protective Levee System (EPLS) defined by the L-31N/C-111 canal and levee system.

3.5.3.1 Expectations for ISOP/IOP

As part of the RPA identified in the Biological Opinion of February 1999, the Fish and Wildlife Service recommended that hydroperiods in the Rocky Glades be increased to something more compatible with sustaining a marl prairie. Construction of L-31N in the late 1960's significantly reduced water levels and hydroperiods in this area, and this was exacerbated by lowered water levels in L-31N in the early 1980's. The Biological Opinion recommended the hydrological equivalent of Test 7 Phase II for the Rocky Glades. The implementation of the ISOP in 2000 actually reduced canal stages below Test 7 Phase I, although a new pump and reservoir, S-332B, was added to increase water levels in the vicinity of CSSS subpopulation F. In IOP another pump station and reservoir, S-332C, was built to further compensate for the lower L-31N canal stages by increasing hydroperiods locally. Thus, the expectation for ISOP is that there would be an observable increase in hydroperiods in the northern end of the Rocky Glades, while IOP should see these benefits spatially increase.

3.5.3.2 Analysis of ISOP/IOP

For analysis of ISOP/IOP effects on the Rocky Glades, the relevant gauges are ANGELS, which is the indicator gauge for the 8.5 SMA (the trigger allowing water managers to provide flood protection through S-331 manipulations), RG-1, and RUTZKE. The plots for ANGELS, RG-1, and RUTZKE are shown in Figure 48. The effects of the proximity of L-31N are clearly shown in these plots. The flood control operations of L-31N allow water managers to maintain a fairly constant upper limit on the water levels and moderate inter-annual variations. Flood protection operations involve maintaining lower canal levels and a rapid removal of water following a rainfall event. However, removing the surface water immediately as soon as possible after wet season rains often results in rapid recessions and extremely low water levels during the dry season. These operations have significant regional impacts and extend well into the wetlands of ENP as shown by the plot of RG-1. These unnatural intra- and inter-annual variations are a concern in the wetlands adjacent to L-31N, primarily to the wet season disposal of flood waters and the lack of dry season surface water.

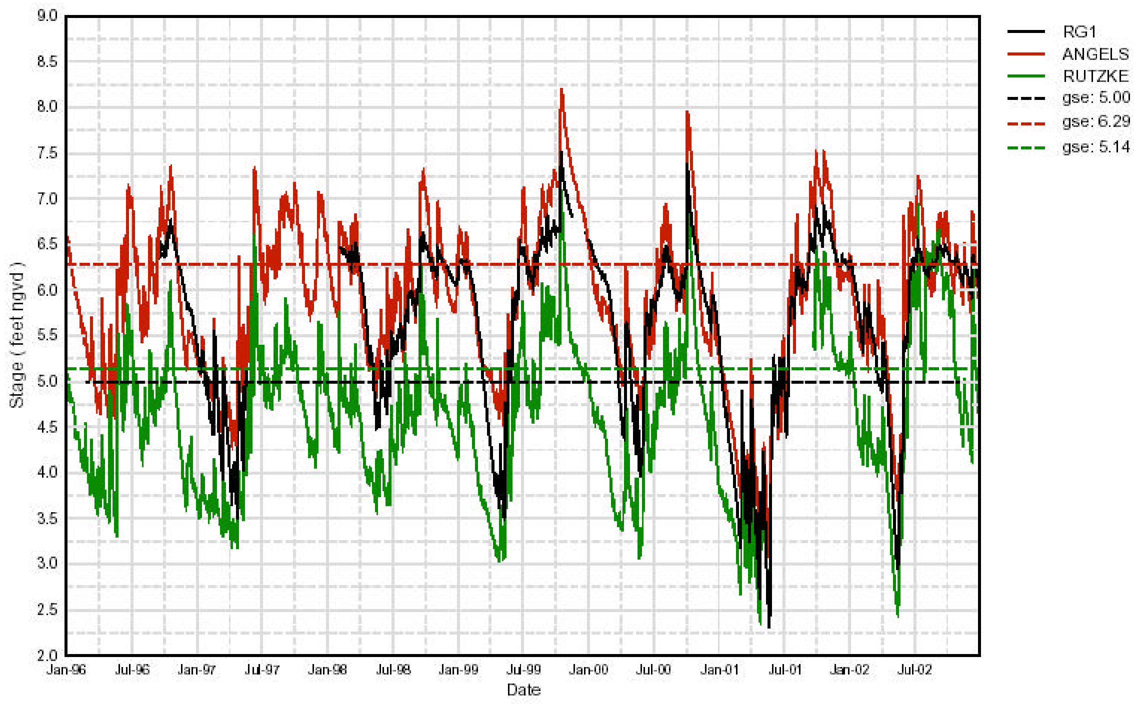

Figure 48. Water levels in Rocky Glades: ANGELS, RG-1 and RUTZKE.

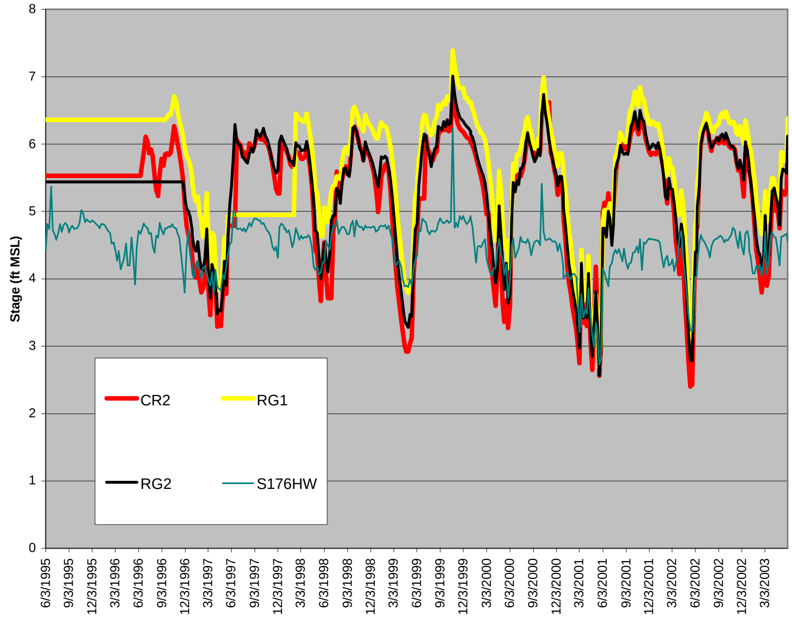

Figure 49. Rocky Glades Water Levels

Trying to determine the effects of the ISOP/IOP on the Rocky Glades is made very difficult by the lack of hydrologic information. For example, Figure 49 is a plot of Rocky Glades water level gages that would be expected to show effects from IOP. However, there is no good concurrent record until early 1998. Given this short period, it will be difficult to make to detect all but the most obvious changes. Moreover, the gages are relatively sparse, and this network may not be able to detect localized impacts.

It is difficult to notice any obvious pattern in the water level traces in Figure 49. Gauges RG2 and CR2 plot almost on top of one another, even though they are almost 3 miles apart. This flat north-south gradient suggests very non-existent surface water flow southward, which would have been the direction of flow based upon topographic gradients. Rather, the strong hydraulic gradient is to the west, towards L-31N canal as indicated by the lower S-176 headwater stages. It is this drainage effect that results in loss of surface water and the degradation in habitats.

These ISOP/IOP modifications to L-31N canal stages are clear in Figure 50. Prior to January 2000, headwater stages at S-176 fluctuated between 4.75 and 5.0 ft msl. With the implementation of ISOP, headwater stages fluctuate between 4.5 and 4.75 ft msl. There was considerable concern on the part of the National Park Service scientists that this reduction in canal stage would translate into increased losses from the Rocky Glades marshes.

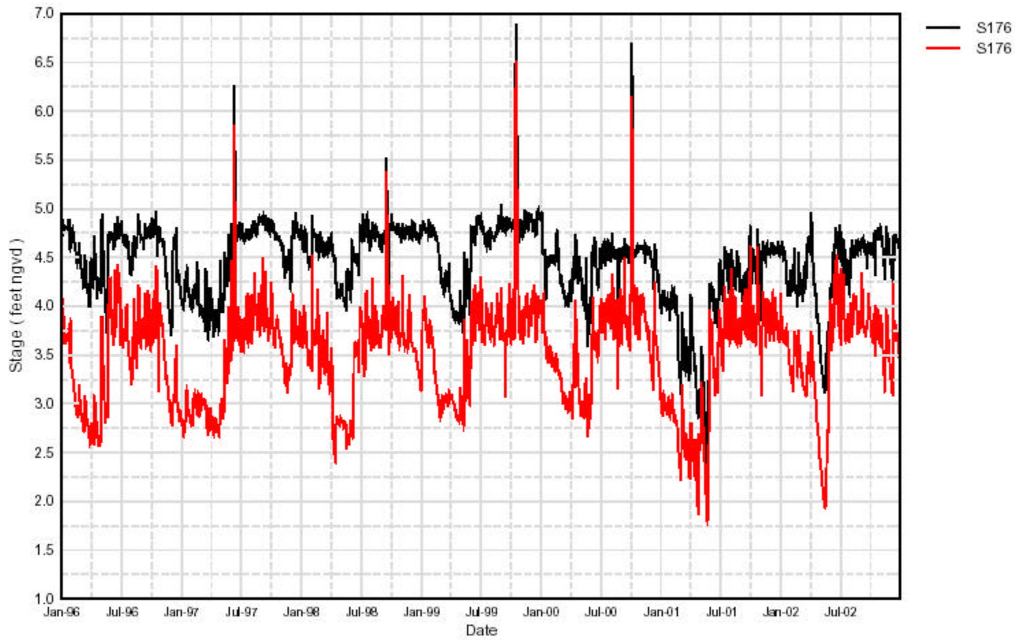

Figure 50. Water levels at S-176.

If one looks for the most likely hydrologic indicators of benefits from the detention areas, there would be several possibilities. First, one might observe an increase in the water level differences between the northern end of the Rocky Glades and the southern, suggesting a north-to-south surface and/or groundwater gradient. Second, one might note an obvious increase in water levels and lengthening of inundation period. Thirdly, one might observe a decrease in the regional west-to-east surface and groundwater gradients, suggesting that drainage losses had been lessened. Let us begin by examining the first case.

Figure 51 is a comparison of RG-2 and CR-2, which roughly parallel L-31N in the former surface water pathway between Shark Slough and Taylor Slough. We have smoothed the water level differences to amplify any trends. The difference between these two gages fluctuates seasonally, but there is no readily apparent change in the difference when ISOP/IOP began in 2000. Thus, it does not appear likely that ISOP/IOP resulted in increased surface water flow in the head waters of Taylor Slough into the main slough.

To determine if there is any apparent increase in depths or decrease in seepage losses, we will examine the data along two transects. The first is along NP-206 to RG-2, which should be related to the effects of S-332B. The second is along CR-2 to G-3622, which should be related to S-332D and L-31W. Figure 52 is the plot of water levels and differences at the NP206/RG2 transect. While it does not appear that NP-206 increased in peak water levels, it would appear that peak RG-2 water levels did increase very slightly, even as L-31N water levels decreased. Moreover the net difference between the two gages appears to have decreased, in both the wet season and the dry. This suggests that the S-332B reservoir may have slightly improved hydroperiods in the vicinity of the reservoir and decreased seepage loses out of the marshes to the west. At the very least, it is encouraging that no drop in water levels corresponding to the drop in canal stages was observed.

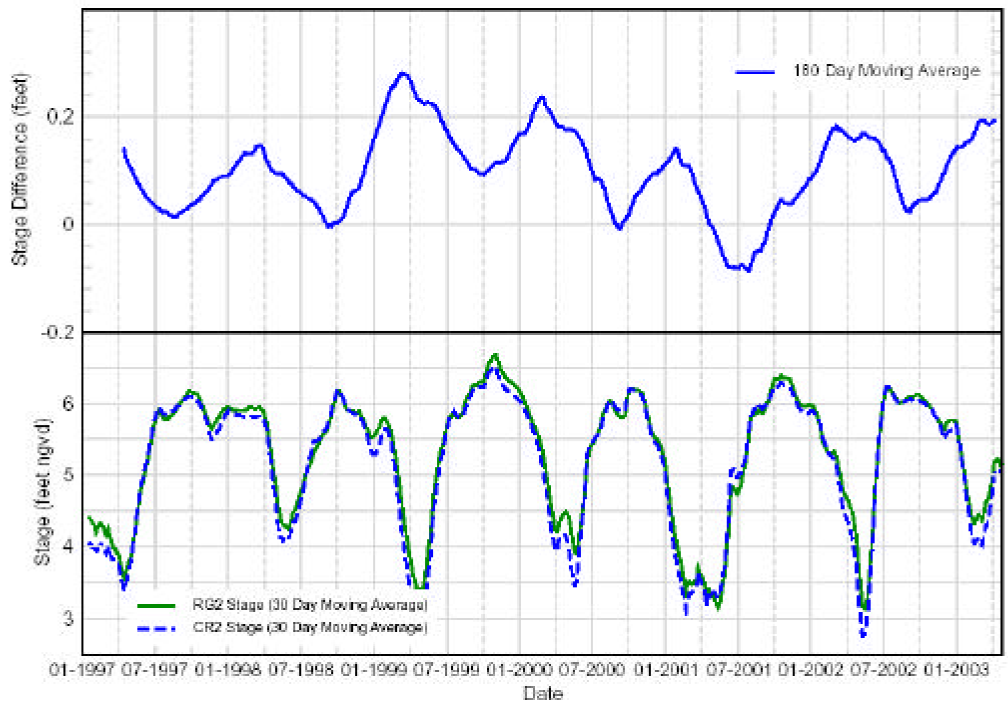

Figure 51. Stage difference between RG-2 and CR-2

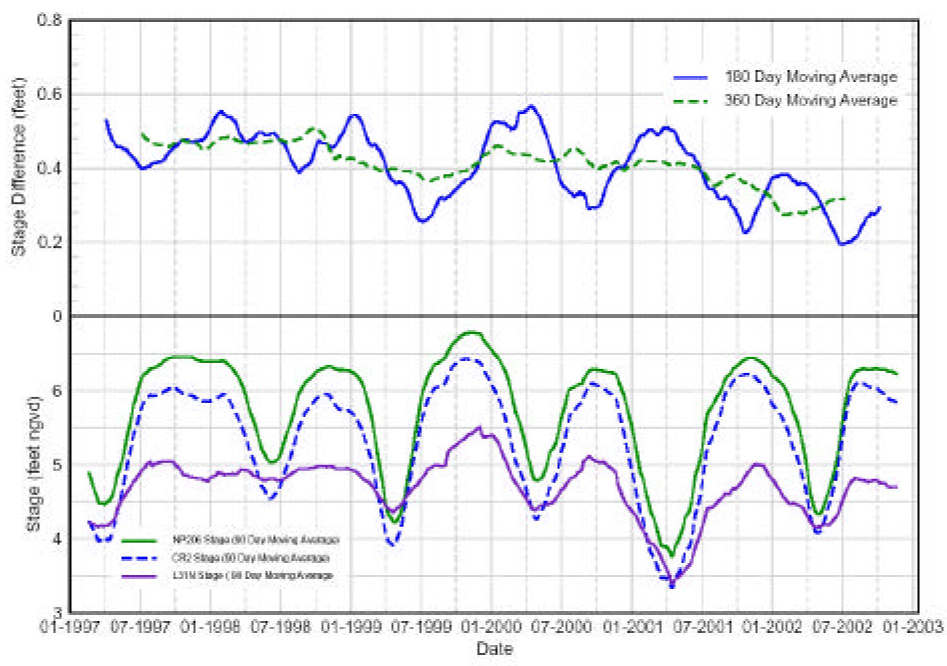

Figure 52. Stage difference between NP-206 and RG-2

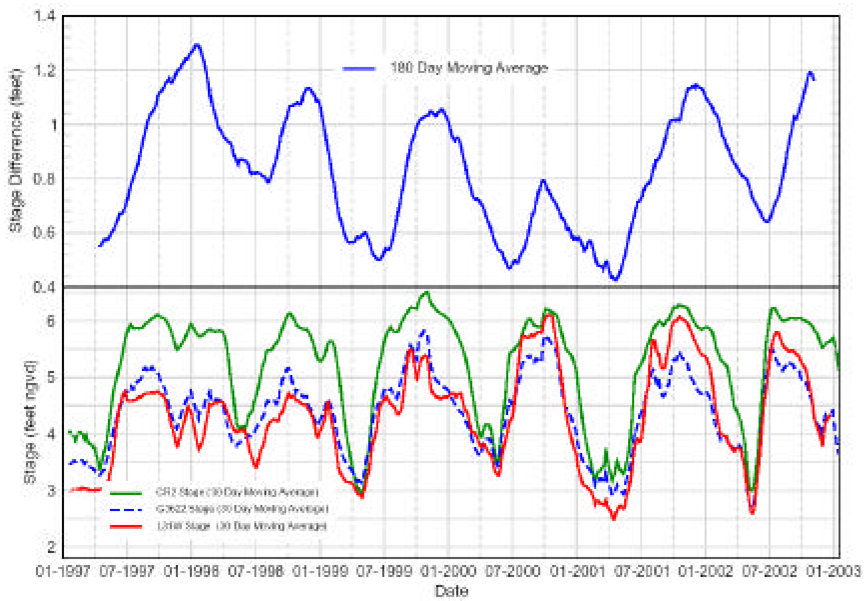

Figure 53. Water levels and differences at CR-2, G-3622, and L-31W canal.

Further to the south, the picture is more complicated. Here, both S-332C and S-332D operations could affect the situation. Figure 52 plots the CR-2/G-3622 transect water levels and differences. There does appear to be a slight peak water level increase at CR2. This increase occurs prior to S-332C coming on-line, and seems to track closer to the L-31W stage, included for reference. There even seems to be an increase at G-3622, again closely tied to L-31W water levels. So, it is possible that S-332D pumping regime had some beneficial effect as far north as Context Road, although that increase would be very small. It is also very difficult to ascertain if the drainage rate decreased, which would be evidenced by a decrease in the average gradient. As with the northern Rocky Glades, the importance might be in that there was no clear increase in response to decreased L-31N water levels.

An important caveat is that the existing network is situated where the S-332B, S-332C and S-332D impacts are most likely to be greatest. That the effects in the northern Rocky Glades were very small suggests that other areas could possibly have seen an adverse effect, though likely small. Another important caveat here is that the temporal averaging used here was between 1 to 6 months. This time scale will not resolve potential effects from pre-storm operations or rapid fluctuations in the reservoirs. One should not conclude from these analysis that pre-storm operations had no adverse affect. Rather, we have no monitoring network in place to detect the localized changes one would expect from pre-storm operations. Hydrologists at the National Park Service strongly suspect that rapid water level changes could induce unwanted marsh response based upon observations of S-332 pumping and nearby marsh response. More information monitoring is required to determine the extent of the marsh responses in the Rocky Glades to localized, short-term reservoir fluctuations.

3.5.3.3 Summary of ISOP/IOP Effects in the Rocky Glades

Any discussion of effects in the Rocky Glades must be predicated with the caveat that the data record is both short and sparse, and this makes analysis difficult. From the available information, it is difficult to detect any significant changes in the Rocky Glades as a result of the ISOP/IOP operations. Most importantly, there did not appear to be any readily apparent adverse effects from ISOP/IOP implementation in the Rocky Glades. S-332B, S-332C, and S-332D operations appear to have at least compensated for lowered canal stages, and there is evidence to suggest peak water levels increased and seepage losses decreased slightly. These operations did not appear to recover any semblance of natural sheetflow, but were rather a direct result of operations and therefore, likely very localized. The existing network was not adequate to determine the effects of pre-storm operations.

We would conclude from this that IOP has provided evidence that the buffer reservoir concept could work, but also that considerably more needs to be done to move the Rocky Glades towards natural conditions. Reservoir operations should be tied to marsh conditions, and CSOP needs to investigate how to improve storage capacity while minimizing reservoir fluctuations.

3.6 Upper Taylor Slough

Figure 54 is a map of the area this report is defined as "Upper Taylor Slough". Of particular note is pump station S-332D, at the confluence of L-31N and L-31W. This pump allowed water levels in L-31W, which borders ENP, to exceed water levels in L-31N while still maintaining 500 cubic feet per second discharge from L-31N. This pump was designed to replace S-332 as the primary inflow point into Taylor Slough.

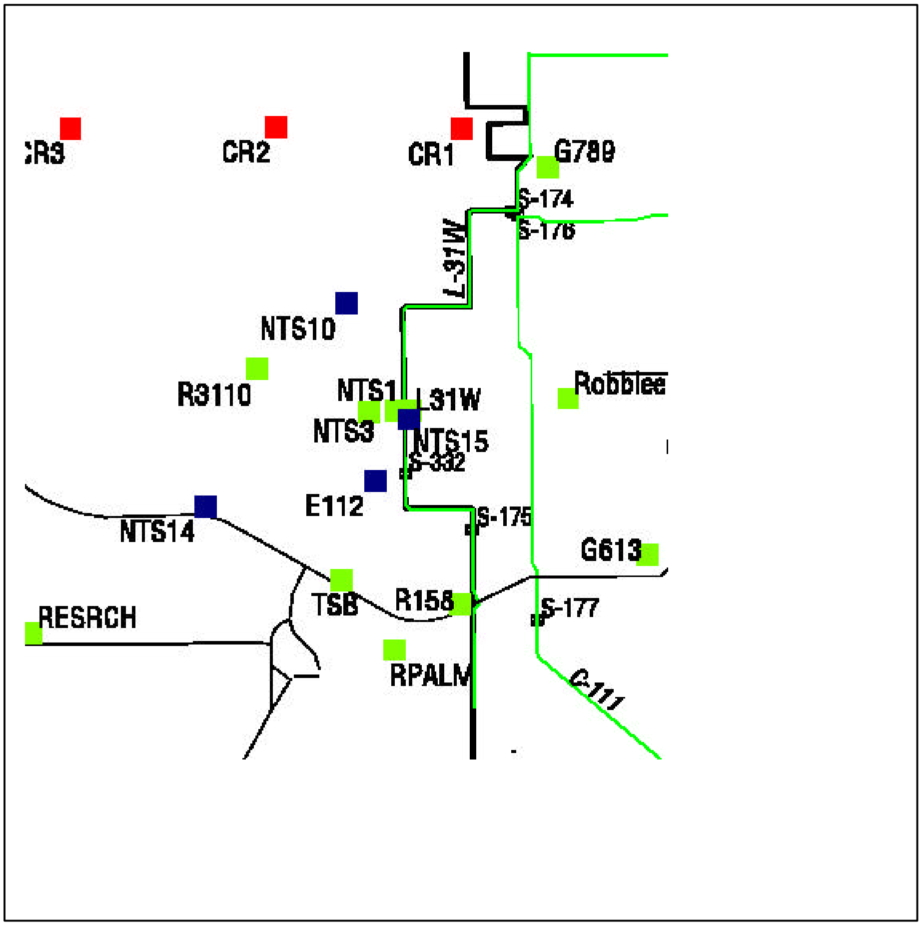

Figure 54. Location map for structures, canals, and water level recorders in Upper Taylor Slough.

There are several water level gauges of interest in this analysis. The northern most gauges looked at in this section is R-3110, located approximately 2.5 miles west of L-31W. Moving down the slough, E-112 is located about midway between the S-332 discharge location, and Taylor Slough Bridge, where SR 9336 crosses Taylor Slough. Station R158 is located just at the entrance to ENP along SR 9336. Further down Taylor Slough, R127 is located approximately 2 miles south of SR 9336 in central Taylor Slough.

3.6.1.1 Expected ISOP/IOP Result

During the Experimental Water Deliveries Program, the objective for Taylor Slough was to increase flows, water levels, and hydroperiods in upper Taylor Slough, and make the water level response more natural, i.e., less a function of pumping schemes and canal stages and more a function of rainfall and flow-based water level recession. The concern was that the pumping regime, which is tied solely to water levels in L-31N and not to any conditions in the marsh, could induce unnatural water level fluctuations and artificially steep recessions.

3.6.1.2 Analysis of ISOP/IOP

The removal of the spoil material on the west bank of L-31W, north of S-332, the construction of S-332D and the detention basin in the Frog Pond allowed for substantial operational changes at the S-332D, S-174/S-176 structures. Pumping at S-332D, instead of relying on gravity flow through S-174, raised L-31W water levels sufficiently to produce overbank flow into northern Taylor Slough. The headwater/tailwater stages at S-175 are shown in Figure 55. Here, one notes that while the L-31W stages above S-175 are significantly higher, water levels below S-175 are not. This suggests large seepage losses into the lower end of L-31W and then into C-111.

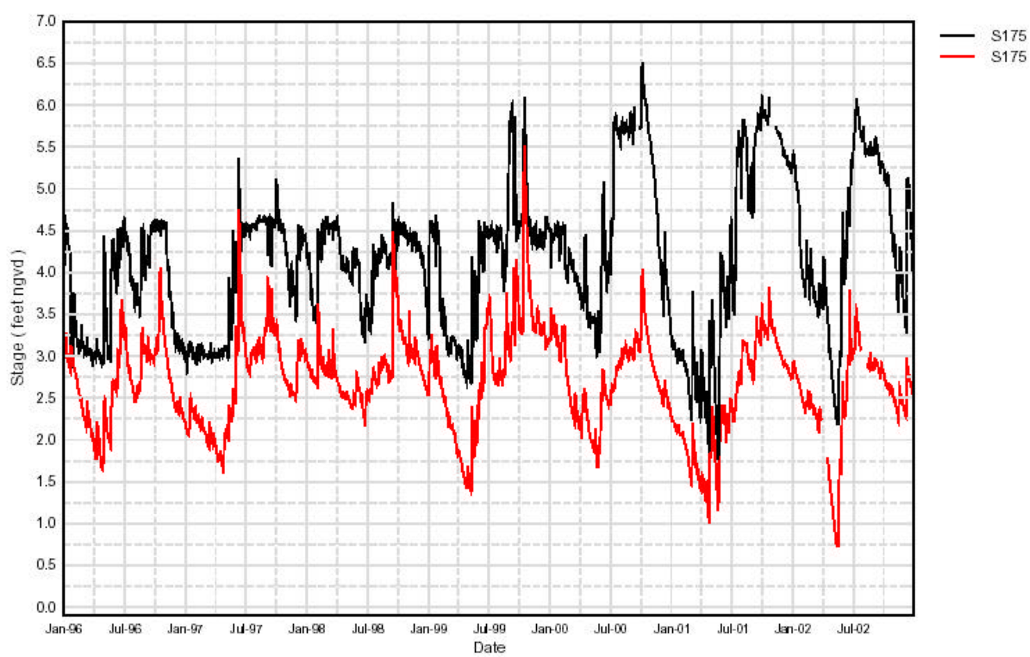

Figure 55. Headwater and Tailwater levels at S-175.

We focus our attention first on the effects that these water levels have had in the marshes. Figure 56 is a plot of observed water levels at R-3110, E-112, and Taylor Slough Bridge. The general picture prior to ISOP/IOP operations is one of high stages corresponding to pumping at S-332, followed by a precipitous decline in water levels when S-332 discharges decrease. One clear feature of ISOP is seen in November 1999 through May

2000. After Hurricane Irene, S-332 and S-332D were pumped continuously at a constant flow rate. Water levels were flat at E112 and Taylor Slough Bridge; the tailwater at S-332 was so high water apparently flowed northward, against the topographic gradient, toward R-3110 for the early dry season. In February, pumping was abruptly terminated, and water levels crashed. Knight (2002) analyzes this operation and the resulting adverse ecological consequences.

During IOP, water levels here appear much more consistent with a natural marsh response. The difference between the three gauges remains relatively constant, indicating uniform surface water flow. Moreover, all three gages responsed with roughly the same magnitude in high frequency fluctuations, which would tend to indicate that this response is occurring in response to individual rainfall events. The IOP hydrographs retain the rapid dry season decline, however. Even in 2001-2002 dry season, which was not particularly severe, water levels at Taylor Slough Bridge dropped to about 0.6 ft above MSL.

This apparent consistency in water level differences is borne out in Figure 57. When S-332 was the primary inflow mechanism, the gradient between R-3110 and E-112 was closely tied to S-332 pumping; when pumping ceased, differences quickly went to zero (indicating no flow). When S-332D and the Frog Pond buffer is used to provide surface flow to Taylor Slough, the difference between R3110 is stable and positive, even when surface flows at Taylor Slough Bridge cease. This suggests that Upper Taylor Slough has a more consistent north-to-south surface water gradient; i.e., the area above L-31W is contributing surface and groundwater flow.

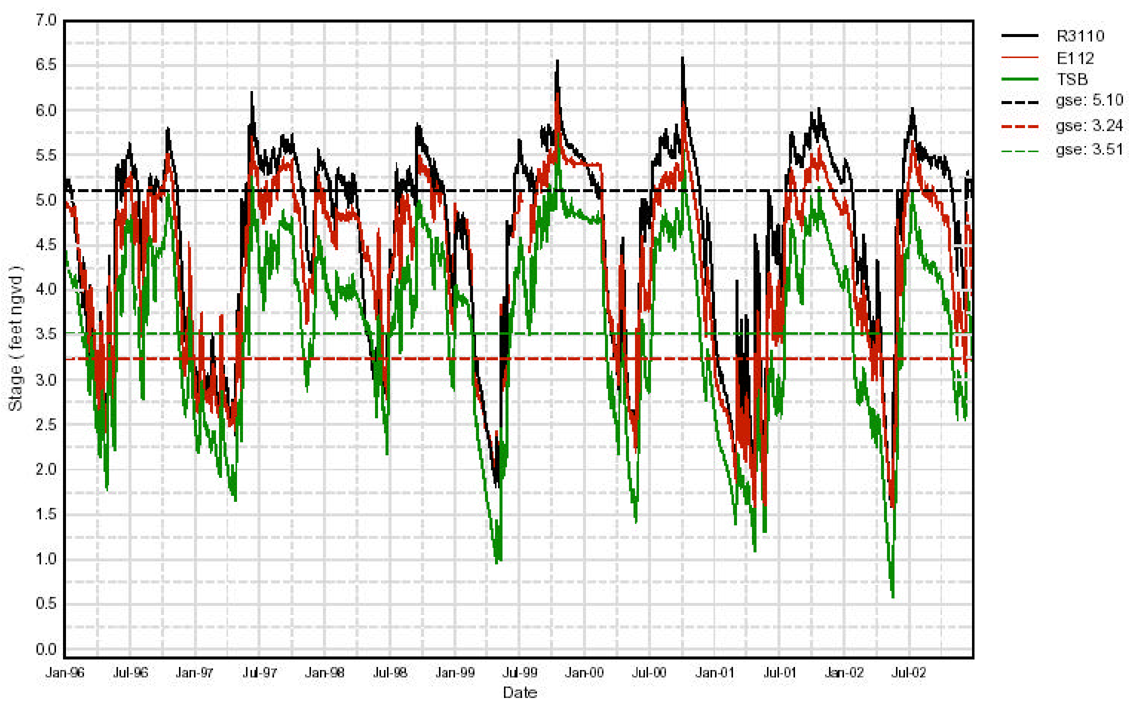

Figure 56. Water levels in Upper Taylor Slough: R-3110, E-112 and TSB

Not only has the north-to-south gradient become more natural, but also the extremely damaging west-to-east gradient (which is proportional to the amount drained from Taylor Slough by the C&SF Project) appears to have decreased slightly. Figure 58 compares the water levels at Taylor Slough Bridge and gauge R-158, with flows at Taylor Slough

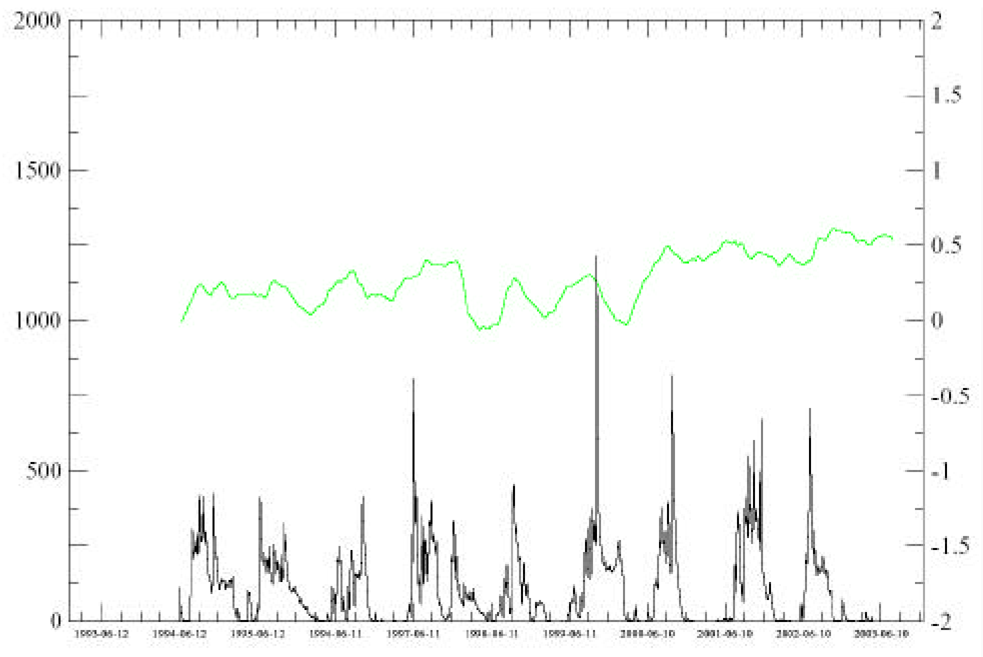

Figure 57. R-3110 and E-112 stage difference

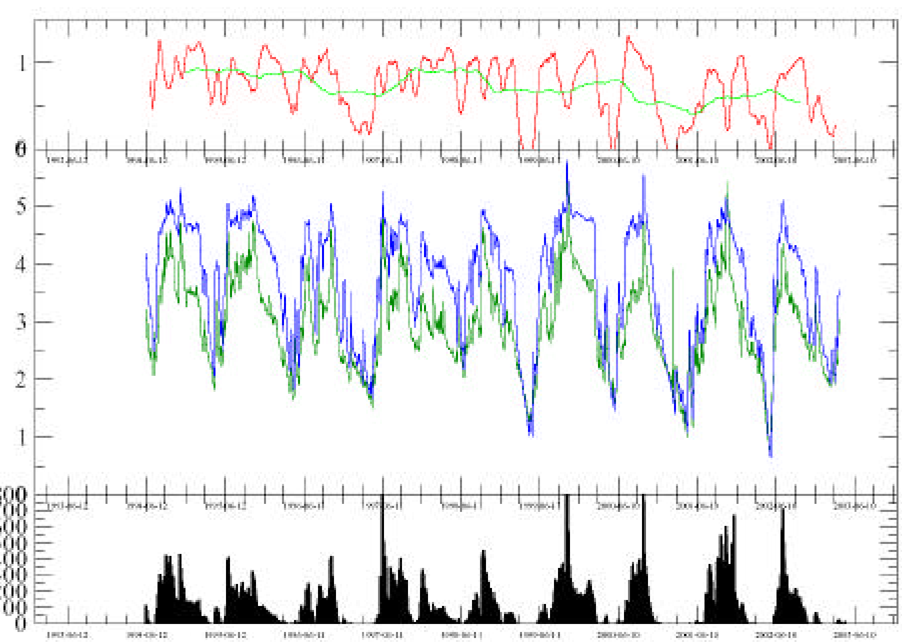

Figure 58. Taylor Slough Bridge and R-158 stage differences

Bridge for reference. The difference in stage between Taylor Slough Bridge and R-158 in both pre- and post-ISOP periods is strongly seasonal. Taylor Slough Bridge levels are maintained by pumping, but R-158 stages are strongly affected by lower C-111 canal stages. This “tug-of-war” continues until pumping ceases, and then both water levels are pulled to the C-111 levels. To smooth out this seasonal effect, we applied a 6-month smoothing window. It appears the net westward gradient decreased slightly after S-332D was used without S-332. If true, this would be a benefit for the natural system in that, at least locally, this area of upper Taylor Slough was not being drained as rapidly as before.

The flows at Taylor Slough Bridge also appear to be increasing relative to rainfall. Figure 59 is a plot of the period of record weekly average discharges across Taylor Slough Bridge. The duration of flow, as well as the magnitude, is apparently increasing. This is consistent with the generally observed increases in hydroperiods and water levels in Upper Taylor Slough.

A closer look at the Taylor Slough Bridge does not suggest that the pre- and post-ISOP/IOP periods have resulted in a substantial change in the rainfall/runoff relationship at Taylor Slough Bridge. The double mass curve in Figure 60 appears unchanged from the time that the pump size was increased at S-332 in 1993.

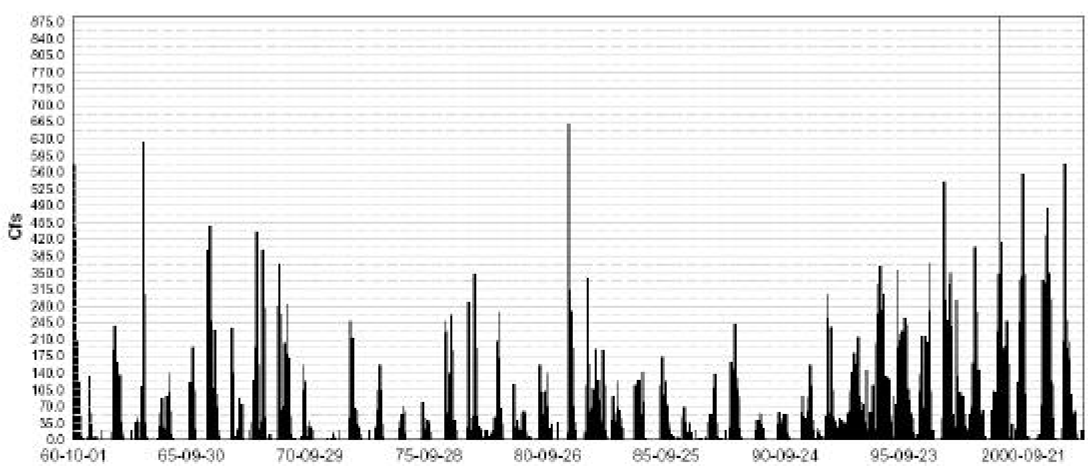

Figure 59. Average Weekly Discharges at Taylor Slough Bridge

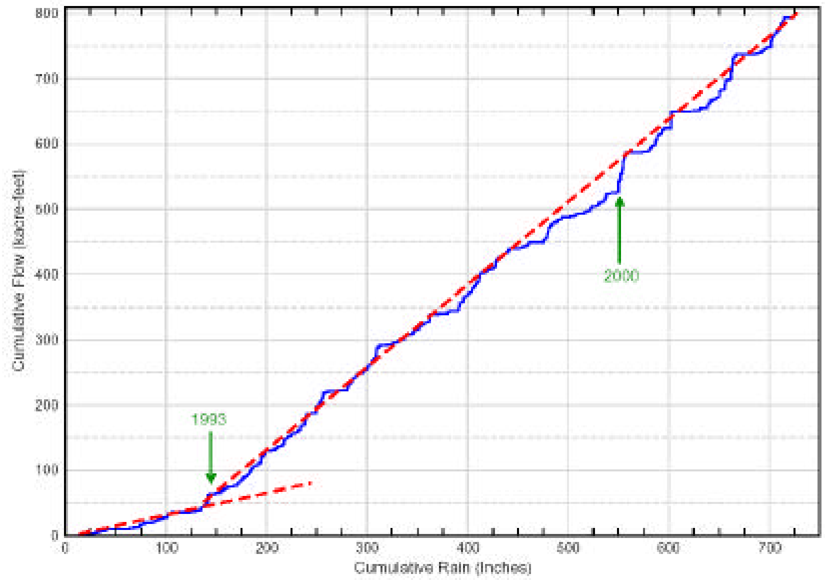

Figure 60. Double Mass Curve of Rainfall at Royal Palm and Flow at Taylor Slough Bridge

3.6.1.3 Summary of Upper Taylor Slough Analyses

A detailed analysis of the hydrologic data in upper Taylor Slough suggests that the period of ISOP/IOP following the abandonment of S-332 has resulted in hydrologic conditions that were more natural than the prior period. Water levels appear slightly higher, with some indication of depth improvements as far westward as Long Pine Key and northward as Context Road. A more natural north-to-south gradient appears to have been established. Additionally, the damaging west-to-east gradient appears to be slightly diminished. This suggests that the IOP implementation has resulted in generally improved water conditions in Upper Taylor Slough. However, operations-induced problems remain. Water levels continue to recede very rapidly to extremely low levels even during moderately wet years, indicating that inadequate wet season storage and depths are maintained in the headwaters to the Slough, and the lower end of the Slough is drained at a too rapid rate.

3.6.2 Lower Taylor Slough and the Eastern Panhandle

South of the Coastal Ridge, Taylor Slough expands and eventually broadens into the coastal mangrove area. Water levels in this lower end of Taylor Slough are strongly influenced by the nearby C-111 canal, which cuts through the historical coastal prairie. This canal discharges water through the S-18C structure and thence via overbank flow into the Eastern Panhandle. This former marl prairie feeds the estuaries of Northeast Florida Bay. (See Figure 61 for a location map).

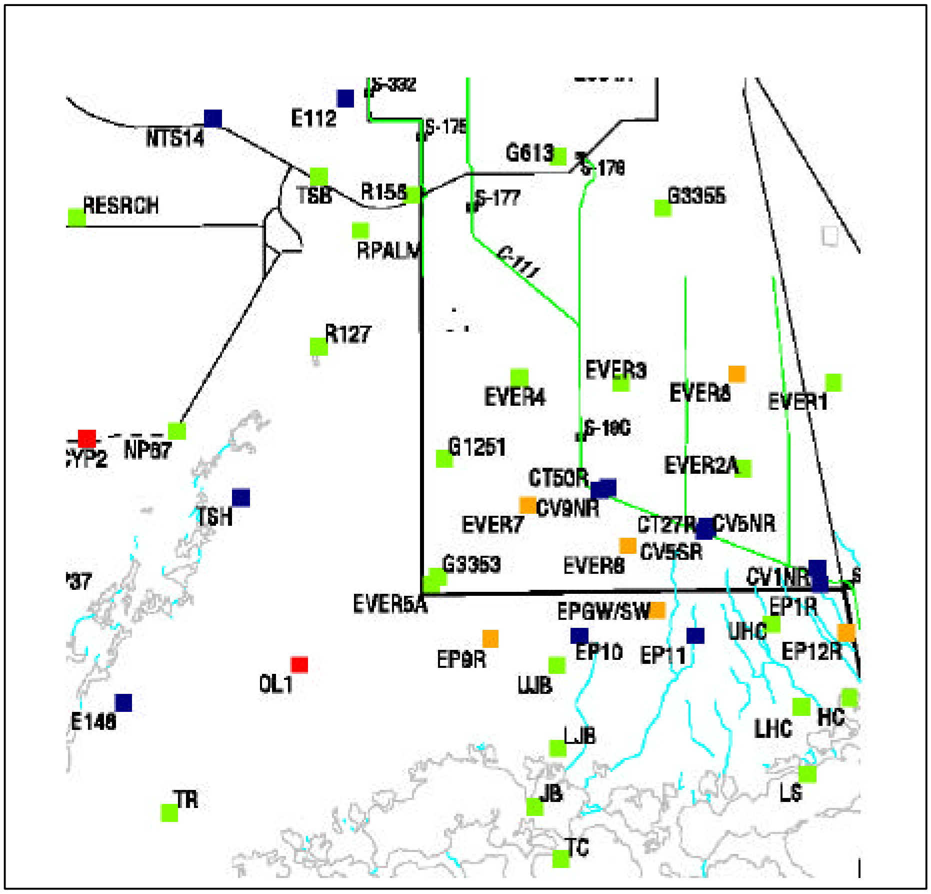

Figure 61. Location map for features in Lower Taylor Slough and the Eastern Panhandle.

3.6.2.1 Expectation for ISOP/IOP

In ISOP/IOP, the ecological objective was to reduce the inflows into C-111, and especially into lower C-111. The large increases in discharge from lower L-31N stages, concurrent with the implementation of the Experimental Water Deliveries Program resulted in a number of adverse impacts related to large, poorly timed, pulsed releases. Additionally, the C-111 canal stages tend to withdraw large volumes out of Taylor Slough and into the Eastern Panhandle. The expectation was that decreasing flows into C-111 and diverting them into Taylor Slough would result in more flow into central Florida Bay and less into Northeastern Florida Bay.

3.6.2.2 Analysis of ISOP/IOP Effects

A good place to begin is an examination of S-176 flows. Figure 62 shows the period of record monthly flow totals. While flows during wet season flood releases have not receded to levels prior to the Experimental Water Deliveries Program, they are clearly very much reduced. Moreover, S-332D discharges clearly increased (Figure 63) relative to S-176. Thus, it would appear that ISOP/IOP is successful in one objective of attempting to divert flow into Taylor Slough rather than sending it directly into C-111.

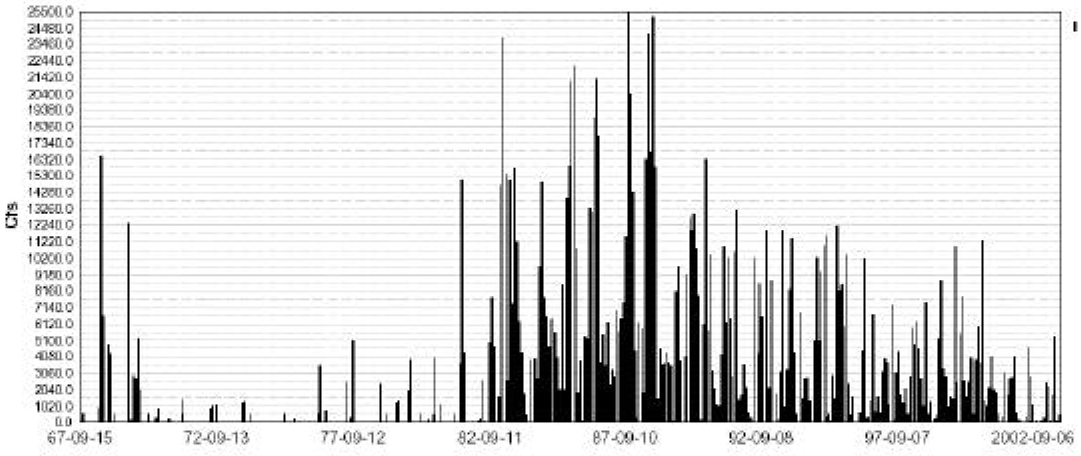

Figure 62. Monthly Flow Volumes at S-176.

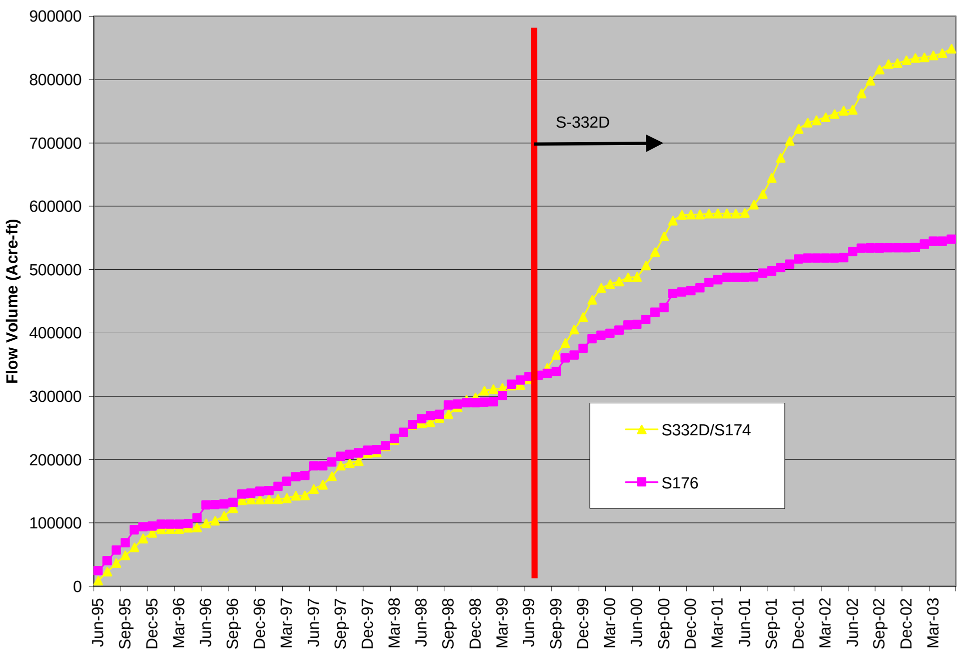

Figure 63. Cumulative Flow Volumes at S-332D and S-176.

This changed S-176 regime does not appear to translate into changes in the structure immediately downstream. When flows at S-177 and S-18C, the structures just downstream of S-176, are examined in more detail, it is difficult to detect any significant change in the flow characteristics from pre-ISOP/IOP to ISOP/IOP (Figure 64 and 65). Flows appear very similar year-to-year, and the pattern seen at S-176 is not apparent here.

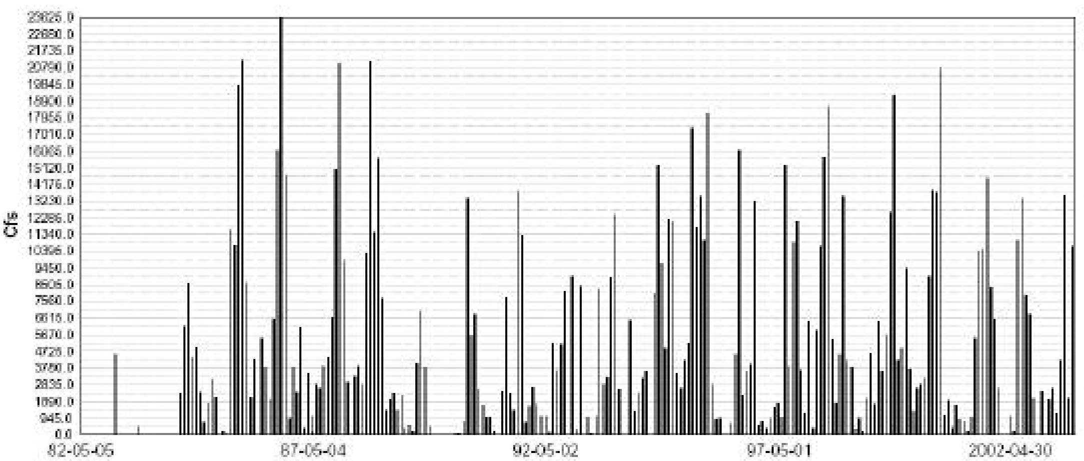

Figure 64. Monthly Flow Volumes at S-177

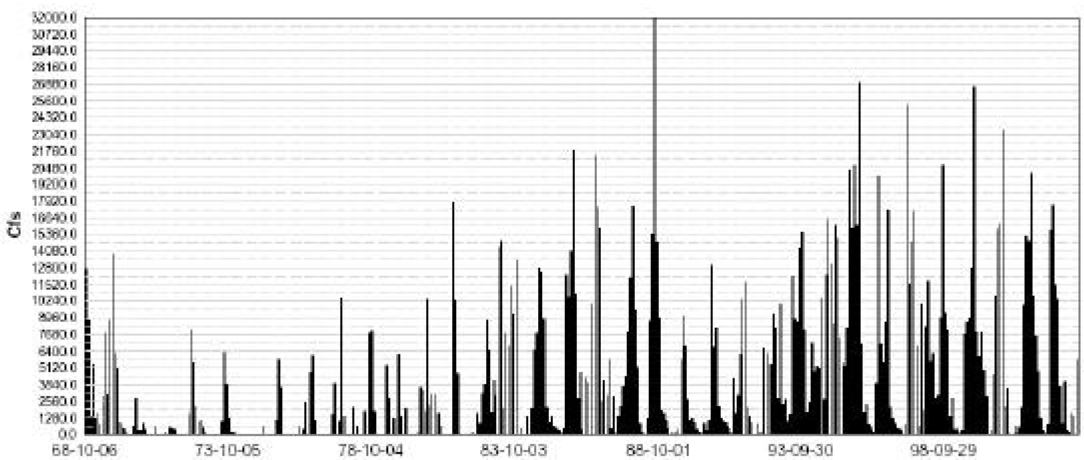

Figure 65. Monthly Flow Volumes at S-18C

A glance at the double mass curves of flow at S-177 and S-18C versus rainfall at Royal Palm (Figures 66 and 67) shows no obvious change in the characteristics of flow relative to rainfall during the period under investigations. It appears that, although direct surface water releases through S-176 have been substantially decreased, flows into the lower end of C-111 (downstream of S-177) have not decreased at all.

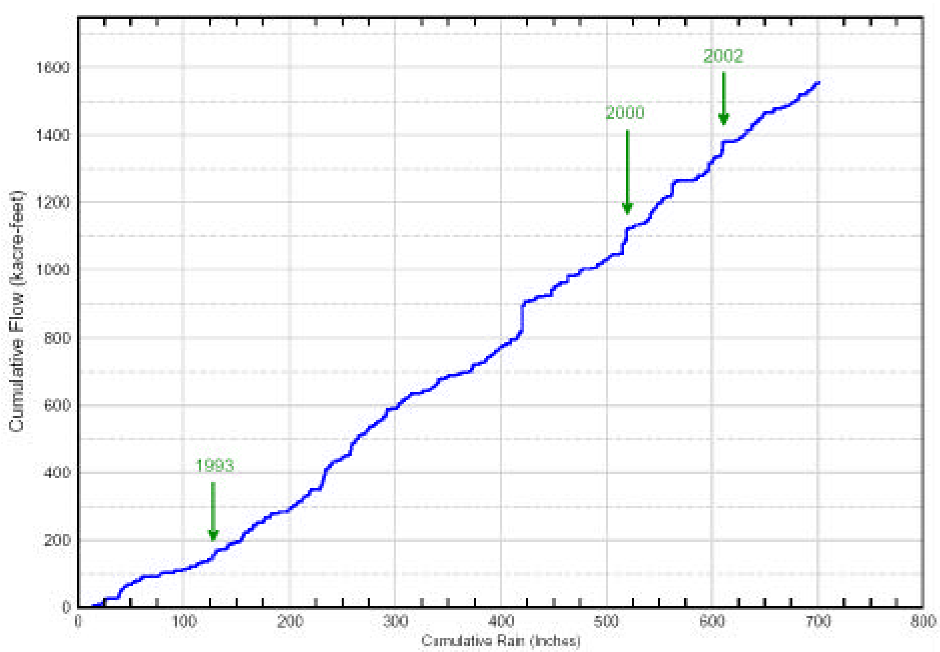

Figure 66. Double mass curve of flow at S-177 and rainfall at Royal Palm.

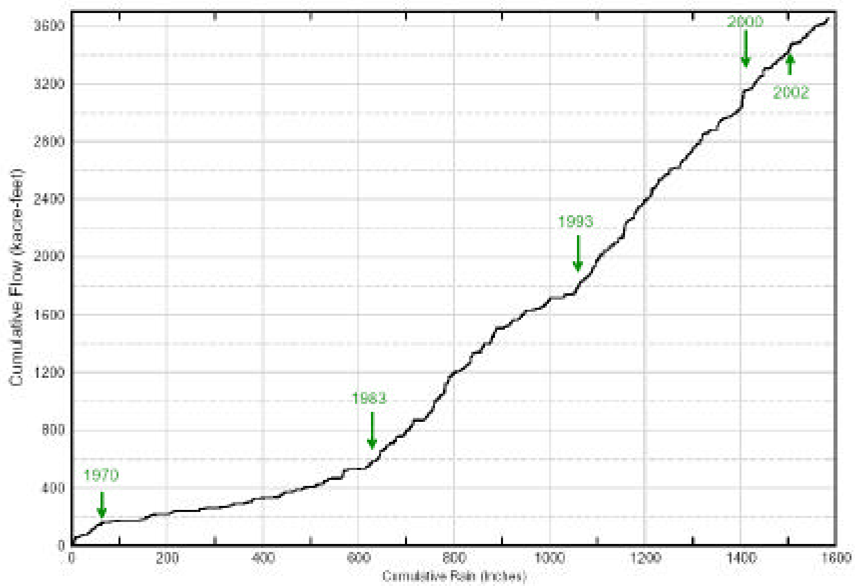

Figure 67. Double mass curve of flow at S-18C and rainfall at Royal Palm

Comparison of combined S-332D/S-176, S-177, and S-18C cumulative discharges (Figure 68) shows that S-18C flow volumes closely track S-332D/S-176 flow totals, which in turn exceed those of S-177. It would appear that, in terms of flow, the benefits derived by operational modifications in upper Taylor Slough were not translated into lower Taylor Slough. Lower C-111 appears to have captured all of the additional water added upstream, and routed it into the Eastern Panhandle rather than maintaining it in Taylor Slough. The increase in slope at S-332D/S-174, is probably a result of the pumping return seepage from L-31N.

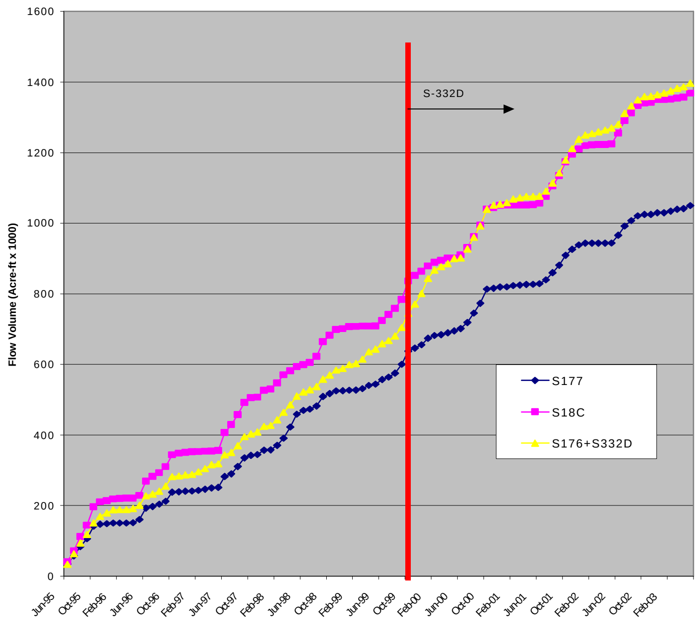

Figure 68. Cumulative flows at S-174/S-332D, S-176, and S-177.

Looking at the effects out in the marshes, gauges R-127, TSH and E-146 are aligned along the axis of the channel (Figure 69). During the dry seasons the gradient between R-127 and TSH becomes very small. Farther south at E-146, the gradient between the gauge and the coastal waters reverses often during the dry season when tidal influence is sufficient to overwhelm Taylor Slough flows during periods of insubstantial releases, and was especially severe in 2001 and 2002. The rapid recession rates observed in Upper Taylor Slough at the cessation of pumping are very quickly transferred downstream, with the result of a very flat gradient all along the slough during the late dry season.

It also appears that effects of pumping in the Frog Pond dissipate as one moves down Taylor Slough. For example, in the dry season of 2000, water level in upper Taylor Slough was constant from November 1999 through February 2000. When flow was cut off, water levels dropped rapidly in upper Taylor Slough. In Figure 69, this effect decreases as one moves down Taylor Slough. At E-146, there is no apparent stage effect from S-332/S-332D pumping.

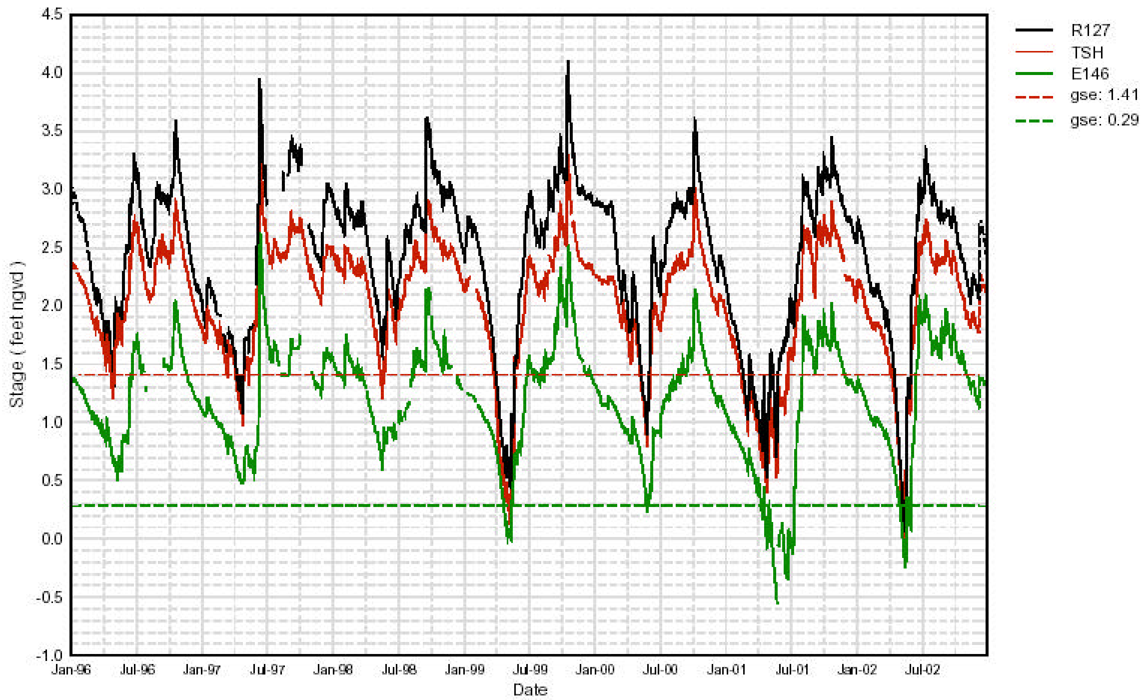

Figure 69. Water levels in Lower Taylor Slough: R-127, TSH and E-146

The surface and groundwater gradients from Taylor Slough toward C-111 are evident in Figure 70. Wet season gradients between R-127 and EVER-4 are very steep, while EVER-4 closely tracks C-111 stages represented here by S-18C headwater. This suggests strong flows from Taylor Slough into C-111, and this is corroborated by the S-177 and S-18C flows. Also clear in Figure 70 is that C-111 serves to recharge the surrounding marsh during the dry season; most years have S-18C headwater stage higher than that of the central part of Taylor Slough for much of the dry season. Apparently, this dry season recharge is insufficient to mitigate for the effects of the wet season drainage, as recession rates seem unaffected by the gradient between C-111 and the marsh.

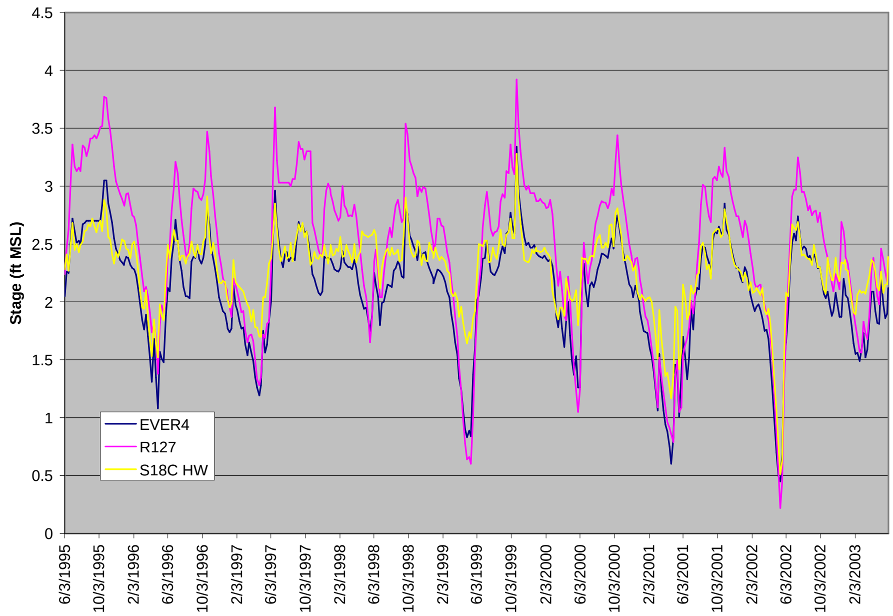

Figure 70. Water levels in lower Taylor Slough and C-111

Looking at upper and lower Taylor Slough together, it is worth speculating on why the large increases in stages in upper L-31W (Figure 54), coupled with lowered criteria at S-176 (Figure 55), had little effect on marsh stages (Figures 68, 69, and 70). The most likely explanation is that water is quickly captured in L-31W below S-175 and discharged into the Aerojet canal and the wetlands at the lower end and flows into the habitat of sub-population D of the CSSS. This "short-circuit" also maintains an eastward gradient in Taylor Slough, continuing to keep much water away from the slough and the western Coastal Prairie.

3.6.2.3 Summary the Effects of ISOP/IOP in Lower Taylor Slough and the Eastern Panhandle

The benefits seen in Upper Taylor Slough do not translate into improvements in Lower Taylor Slough and the Eastern Panhandle, nor do they translate into any apparent additional harms. The lower end of Taylor Slough and the Eastern Panhandle show no significant observable changes with the implementation of ISOP/IOP. The likely explanation is that the lower L-31W (below S-175) and the Aeroject canal serve to drain water from the marsh and deliver it back to C-111. Moreover, wet season operational stages set far below marsh stages results in significant drainage from the Taylor Slough marshes into C-111, resulting in an eastward shift of inflow into Florida Bay.

3.7 Predicted Operations versus Actual

The predictions in the EIS of hydrologic response to ISOP/IOP operations were developed using the South Florida Water Management Model (SFWMM) version 3.8. The SFWMM simulates overland flow, groundwater flow, canal flow and structure flow from Lake Okeechobee to Florida Bay (Figure 71). One important question is: How do the predictions of responses compare to observed responses?

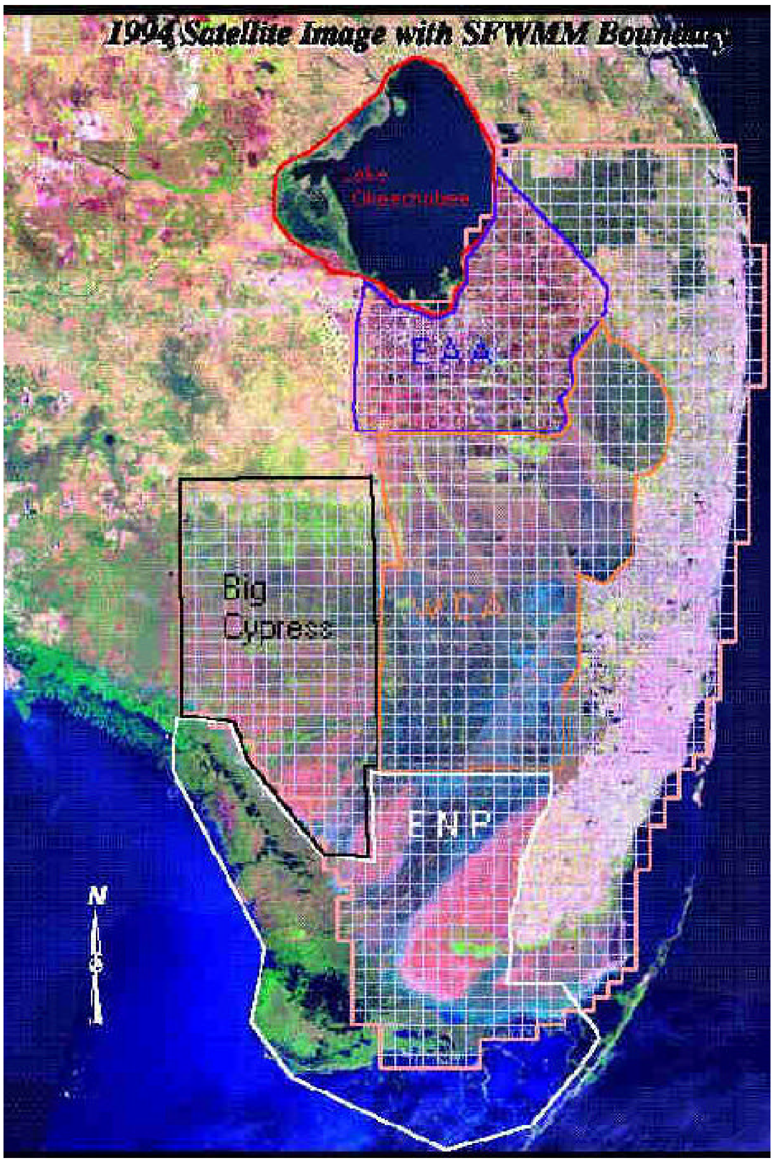

Figure 71. The domain of the SFWMM.

There are many obstacles to a direct comparison. Most of the model results posted from the IOP modeling are aggregated according to calendar year (Jan 1-Dec 31), while the hydrologic analysis in this report relies on wet season, dry season and hydrologic year aggregations. Additionally, the model years are different than the implementation years, so there is no opportunity for direct comparison of model results with on the ground measurements. However, there is an opportunity to compare the average model results to measurements from average years. Since the dry season of 1996-1997 and 2001-2002 (Nov 1- May 31) are slightly drier than average and the wet seasons of 1997 and 2002 slightly wetter than average, these combined wet and dry seasons are very close to average with return frequencies of 0.55 (Nov 1, 1996-Oct 31, 1997) and 0.49 (Nov 1, 2001-Oct 31, 2002). Therefore average year modeling results for IOP will be compared to the period from Nov 1, 2001-Oct 31, 2002 (Table 22). Averages year modeling results from Test 7 Phase I (95BM3 model run) will be compared to Nov 1, 1996-Oct 31, 1997.

Table 22 contains the comparison between the average modeled structure flow and the actual structure flows for average rainfall years during the before and after periods. Table (not shown) contains the "1-in-2" annual return period (median) flows from the SFWMM, compared to the total flow measured before and after ISOP/IOP implementation for a year with a "1-in-2" return period for rainfall. For these comparisons we are emphasizing the differences between the before and after periods rather than the actual value of the structure flows, since the average structure flow does not necessarily occur in an average year. The comparison between median flows and IOP flows is considered most appropriate, since the rainfall for the selected comparison period is the median rainfall.

Figure 72 compares the differences in modeled and measured flows for the Test 7 and IOP simulations. It is apparent from this figure that the actual structure flows vary greatly from the modeled structure flows, but for the most part these variations are consistent between model runs, indicating that the modeled changes in structure flow should be comparable to the measured changes in structure flow. There are a few structures for which the difference between modeled and observed is substantially different between model runs: S-151, S-12B, S-338, S-331, S-174, S-332 and S-197. Of these structures, the largest deviations between ISOP/IOP actual and predicted were for S-338 and S-331. The deviations at S-174, S-332, S-18C and S-197 are relatively small under the IOP runs and large for the Test 7 runs. At S-151 the error is smaller for the IOP runs, but is substantial in both runs, although the direction of the error is different for the IOP and Test 7 runs.

Figure 73 compares the modeled changes in median structure flows with the observed changes (IOP-Test 7). Figure T5 is a similar comparison between modeled and observed average flows. In both figures modeled differences are similar to or greater than measured differences for all but S-332C and the lower C-111 structures (S-176, S-177, S-18C, S-197). The most striking discrepancies between modeled and observed can be seen at S-151, S-12B, S-338, S-331, S-174, S-332 and S-197. These discrepancies are evident in both the average and median flow comparisons.

According to the modeling results, the median flows from S-12B decreases under IOP, while observations show that the flows at this structures increased under IOP. The observed and modeled median flow differences at S-12A, S-12C and S-12D are in close agreement. Therefore the combined S-12 median flows are predicted to decrease under IOP but have actually increased, indicating a discrepancy of about 60,000 acre-ft per year between the modeled and observed inflows to western shark slough. While the modeling predicts very little change at S-338, observed flows at S-338 have increased by 75,000 acre-ft per year under IOP. The model also under-predicts the changes that occur at the S-331 pump station. The model predicts a 20,000 acre-ft per year increase in pumping at S-331 while observed pumping increased by 100,000 acre-ft per year. For the reach of L-31N above S-331 the net inflow discrepancy can be calculated by adding the changes in S-334 and S-335 flows and subtracting the changes in S-338 and S-331 flows and comparing the two net inflow changes. Since G-211 observed and modeled changes are the same, G-211 is not included in the calculation. Modeled average net flow into this reach increases slightly by 9,000 acre-ft per year under IOP. Modeled median net flow into this reach increases by 46,000 acre-ft per year under IOP. However observed flows decrease substantially into this reach by 66,000 acre-ft per year. Therefore the model under-predicts the drainage of this reach by 75,000-110,00,000 acre-ft per year, which is nearly double the observed drainage of 112,000 acre-ft per year. In effect, there is a 100% increase in drainage of L-31N that occurs under IOP that was not predicted by the SFWMM. This discrepancy can be expected to lead to under-prediction of flow changes to the downstream structures (S-332B, C, D and S-174, S-176, S-177, S-18C, S-197) and over-prediction of stages in NESS and the Bird Drive Basin. The model under-predicts flow changes at S-174 and S-332 due largely to overestimating flow at these structures in the Test 7 (95bm3) runs. Similarly, the overestimation of flow increases at S-177, S-18C and S-197 are driven primarily by the over-prediction of flow at these structures in the Test 7 (95bm3) runs.

In terms of flow volume, the most significant difference between modeled and observed changes is derived from the S-331 and S-338 flow volumes, which were under-predicted in the IOP modeling. In the modeling, S-338 flow was determined by on/off criteria that matched table. In reality, S-338 flow was often regulated by matching S-338 flow to S-335 flow, causing actual flows to greatly exceed predicted flows at this structure.
Zone

Table 22. Simulated and observed annual structure flows

	Modeled 31 year average discharge			Observed Annual discharge		
Structure	Test 7 Phase I	IOP average	Difference	1997 (Test 7)	2002 (IOP)	difference
S-9	176	177	-1	285	268	17
s-8	403	382	21	68	24	44
S-337	117	91	26	152	265	-113
S-151	257	295	-38	108	112	-4
S-12A	48	23	25	92	145	-53
S-12B	96	60	36	252	257	-5
S-12C	139	97	42	255	273	-18
S-12D	175	218	-43	65	121	-56
S-335	126	140	-14	96	206	-110
S-333	204	298	-94	0	56	-56
S-334	0	40	-40	220	241	-21
G-211	151	195	-44	70	147	-77
S-338	59	54	5	212	313	-101
S-331 comb	199	249	-50	0	73	-73
S-332B	0	58	-58	0	21	-21
S-332C	0	67	-67	0	113	-113
S-332D	0	93	-93	62	31	31
S-176	96	104	-8	59	19	40
S-174	134	5	129	111	0	111
S-332	165	0	165	104	116	-12
S-177	112	139	-27	162	167	-5
S-18C	127	155	-28	96	16	80
S-197	16	11	5	241	265	-24

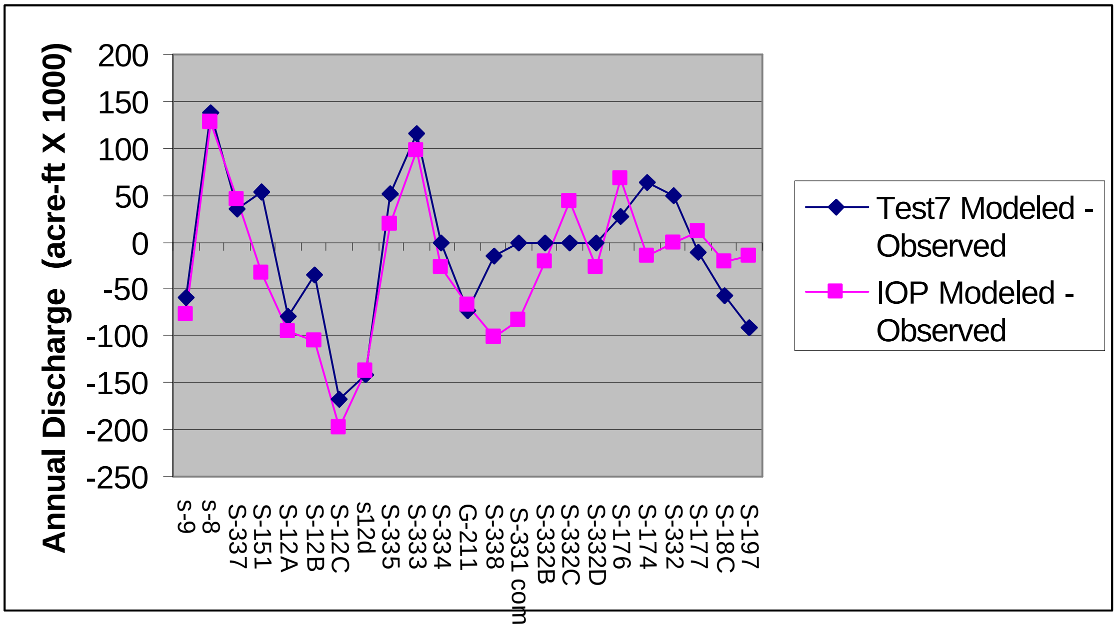

Figure 72. Differences in measured and modeled flows for Test 7 and IOP model runs.

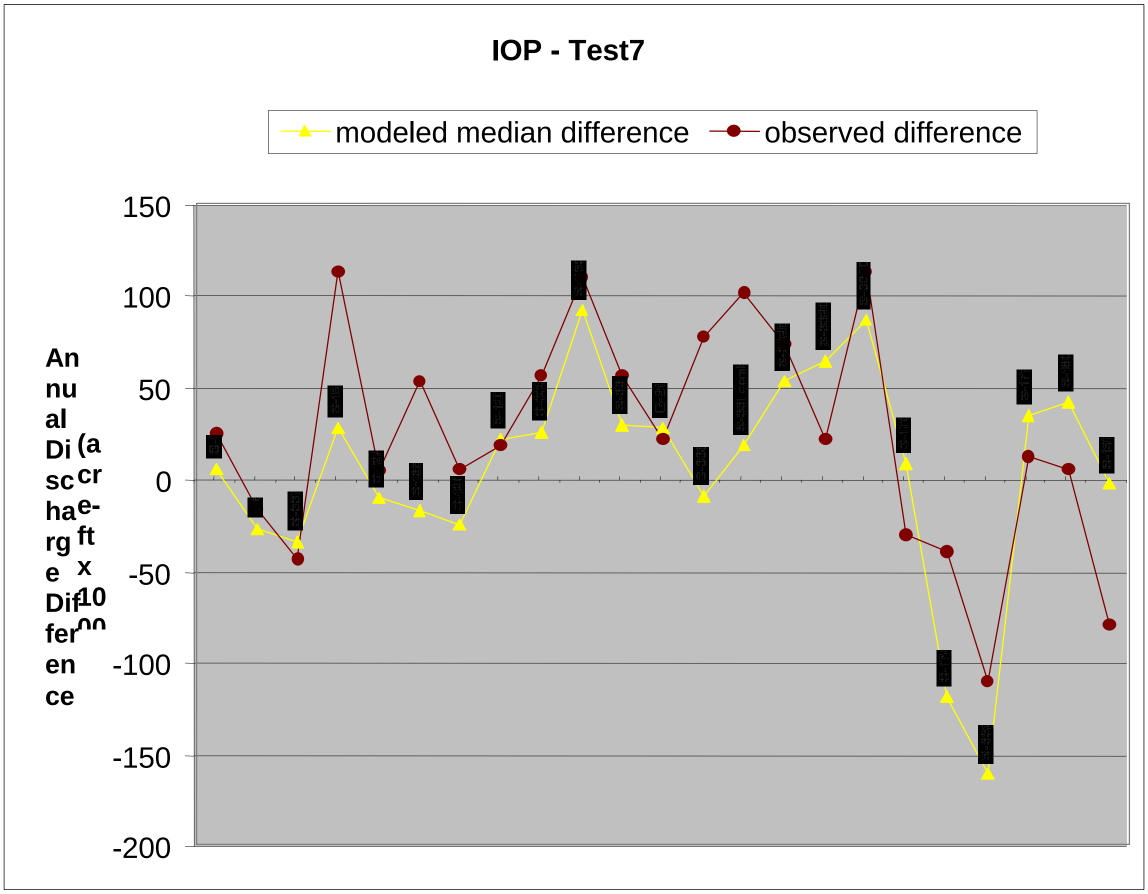

Figure 73. Modeled differences in median structure flows with the observed differences (IOP – Test 7).

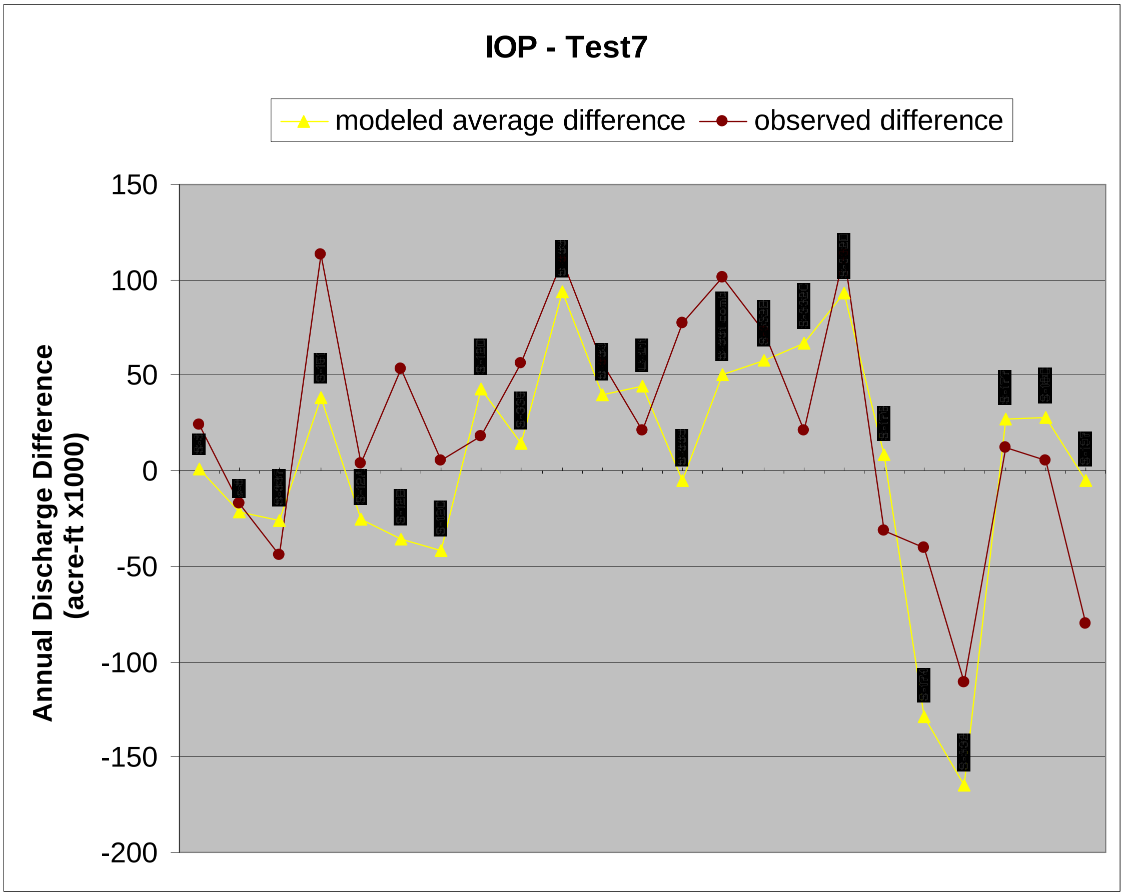

Figure 74. Modeled differences between observed differences (IOP – Test 7) in average structure flow.

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